MAY 1959

JOURNAL OF THE IRON AND STEEL INSTITUTE

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VOL. 192 PART 1

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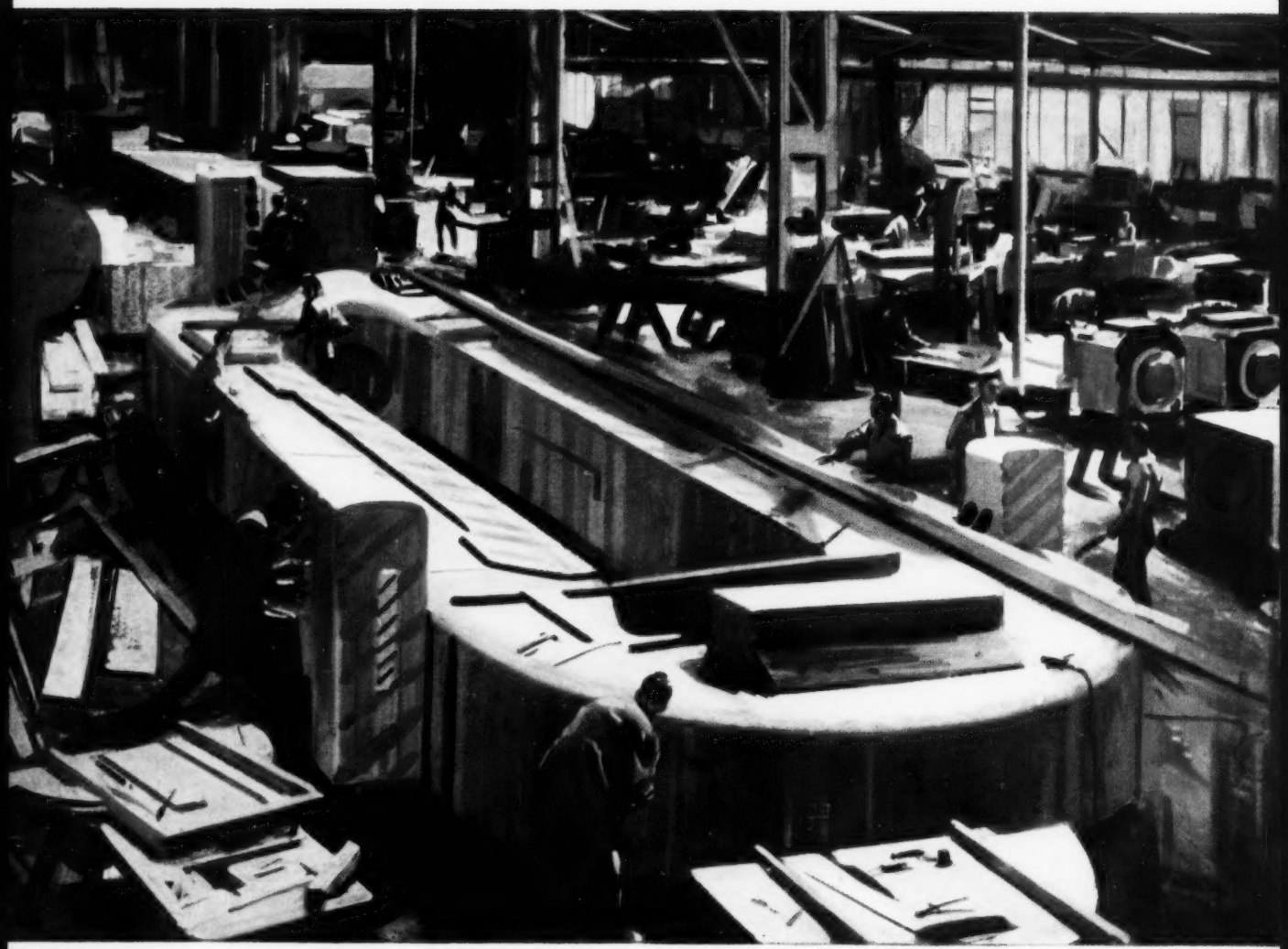
Palette on Production

No. 1 in a series of original paintings specially commissioned from Robert Johnston, R.I., S.M.A., illustrating the productive resources for metalworks plant of Davy-United's Darnall Works. The scene shows the making of a pattern for a roll housing for a 12 foot wide hot plate mill for aluminium. When cast the housing weighed 163 tons while the pattern itself took nearly three tons of timber.



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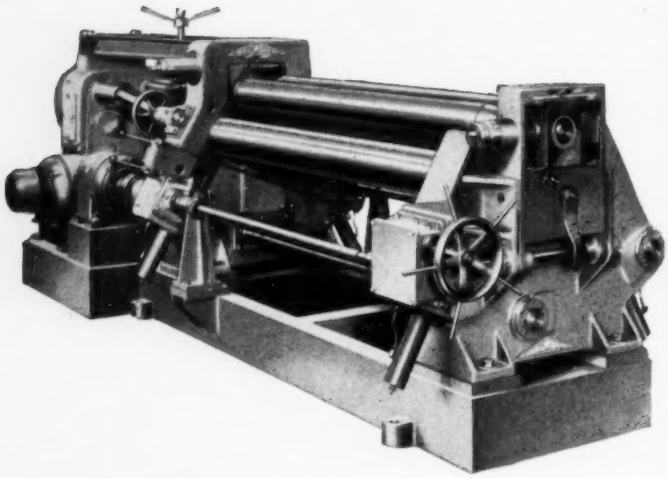

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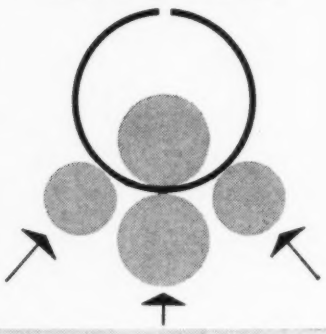

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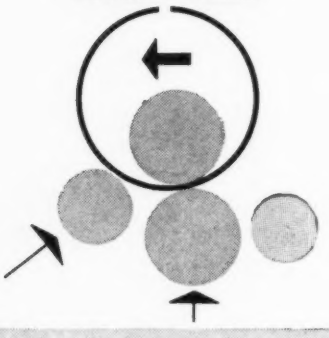

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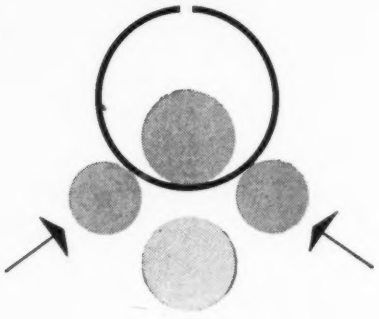

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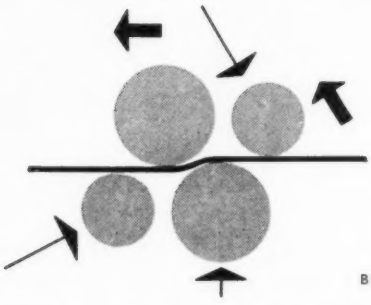

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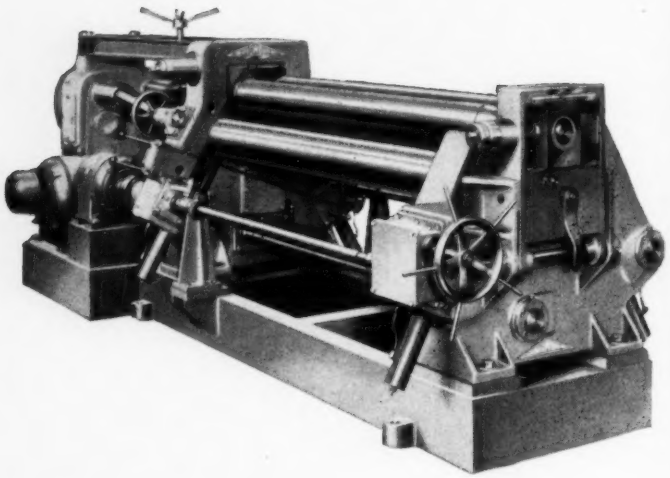

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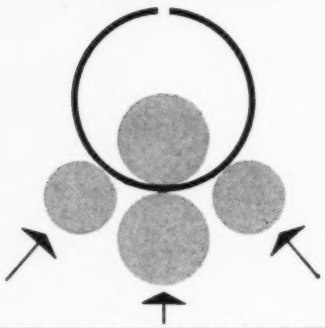

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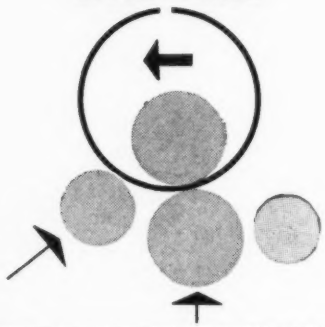

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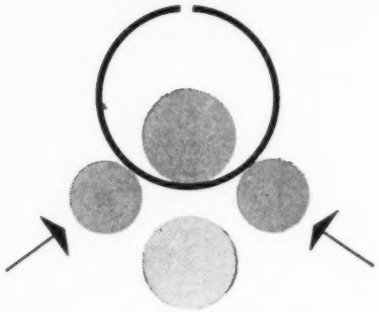

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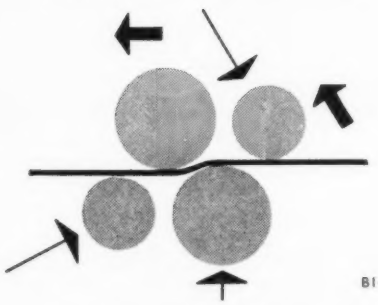

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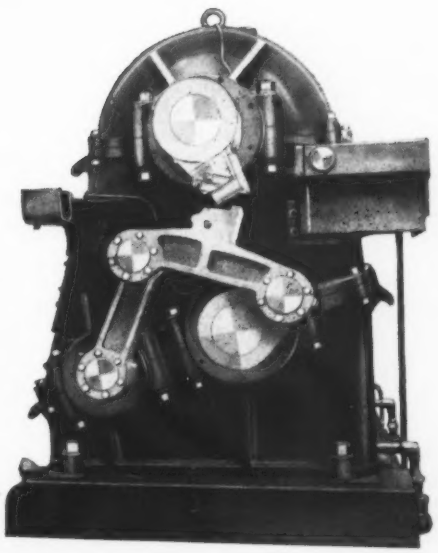

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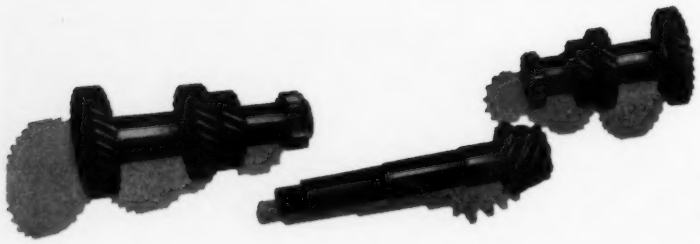

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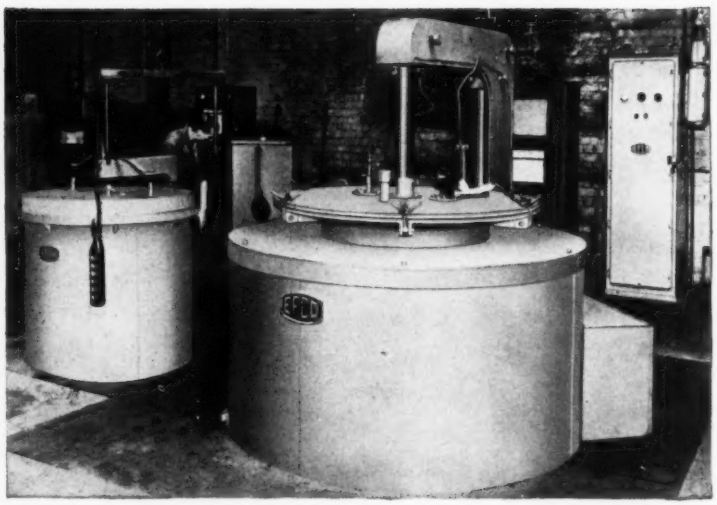

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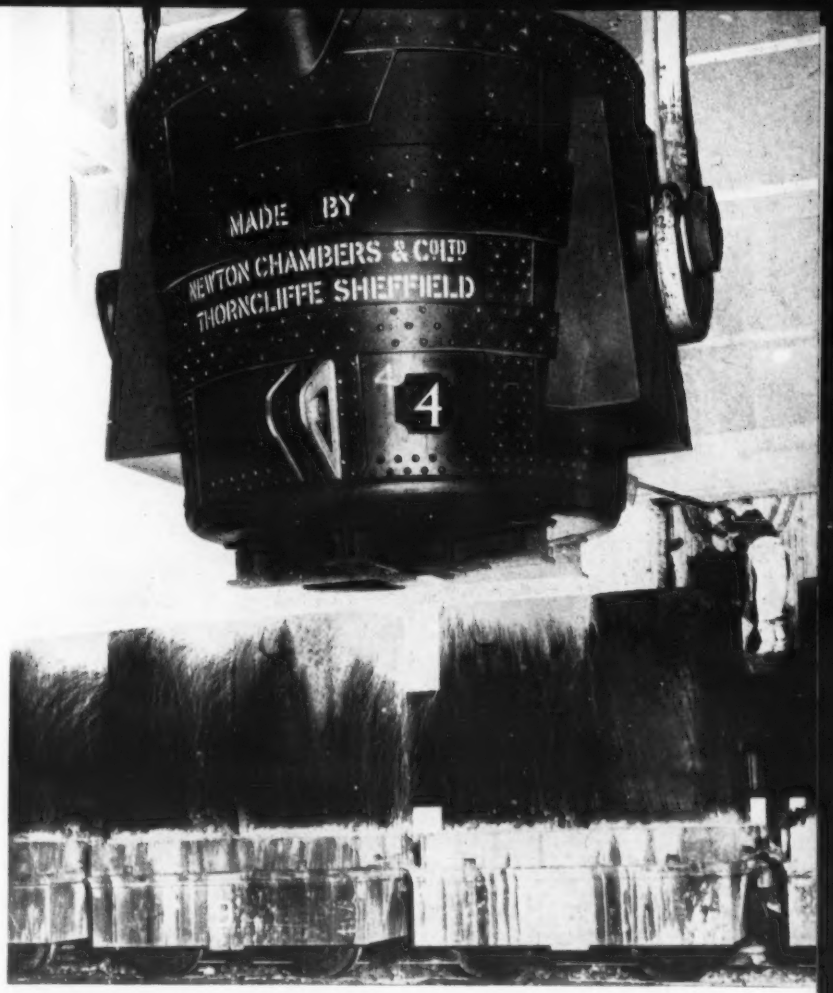
RIGHT *One of many steel casting ladles supplied to John Summers and Sons Limited.*



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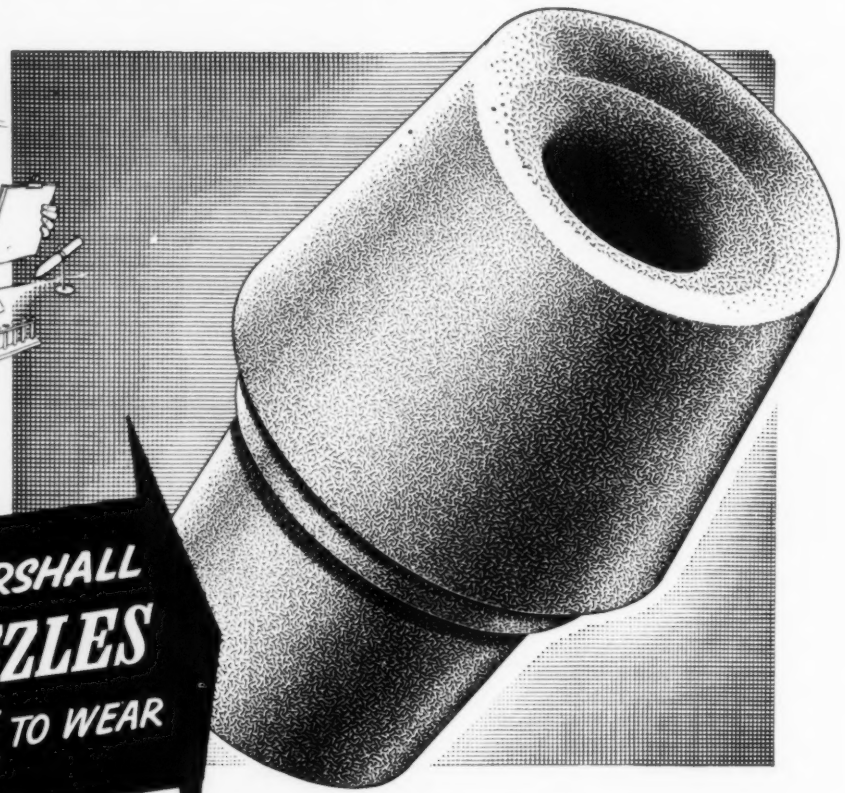

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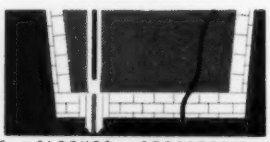

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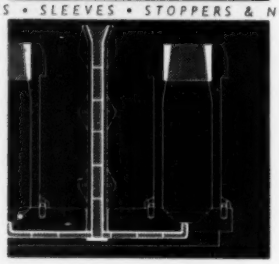

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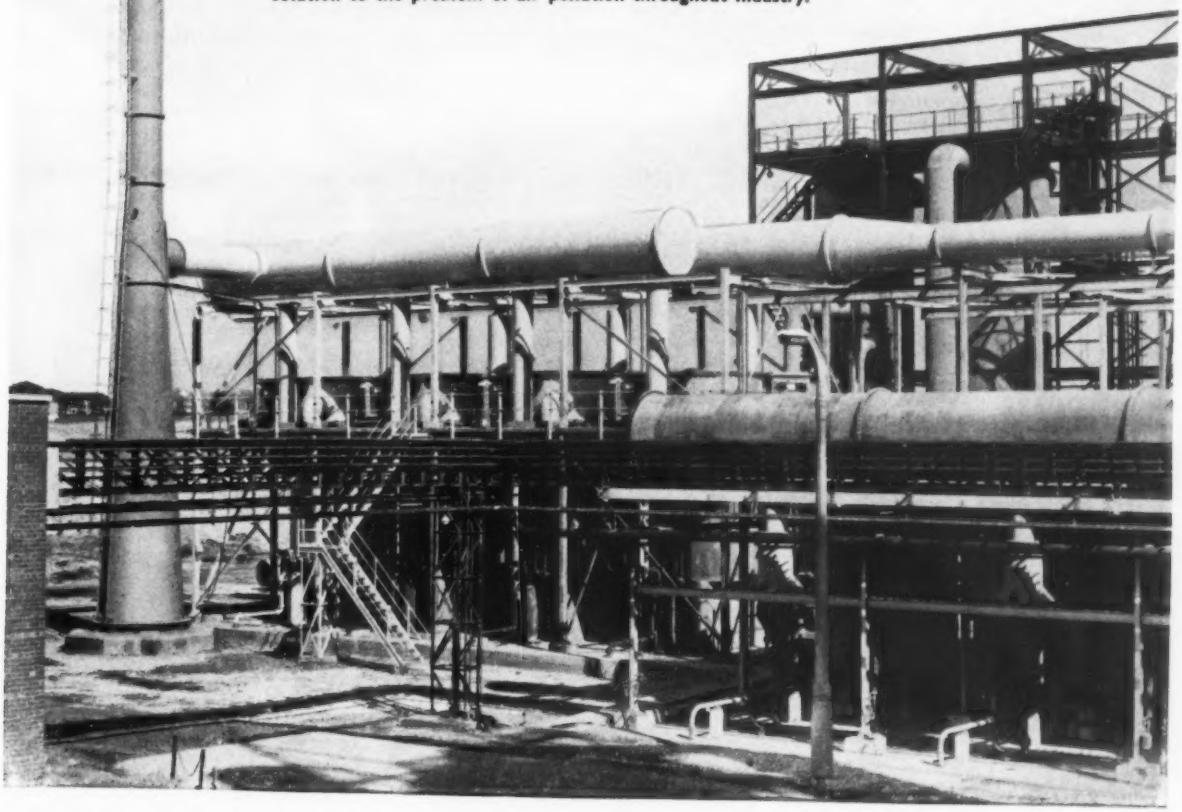

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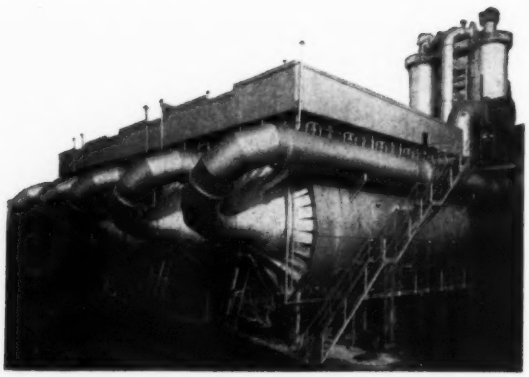

Photo Right: Close up of the five Precipitators installed by Lodge-Cottrell.

Photo Below: View looking towards 3 & 4 Blast Furnaces at Indian Iron and Steel Co's Works, Burnpur, India.

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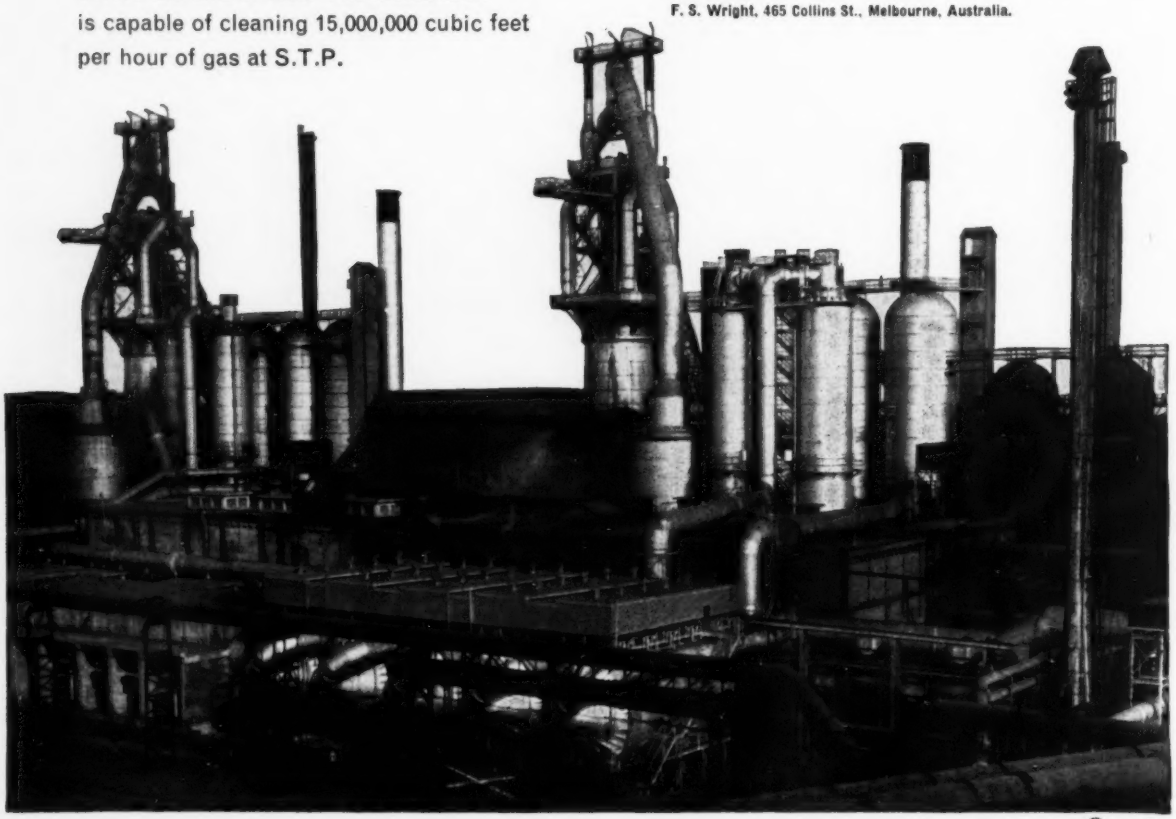
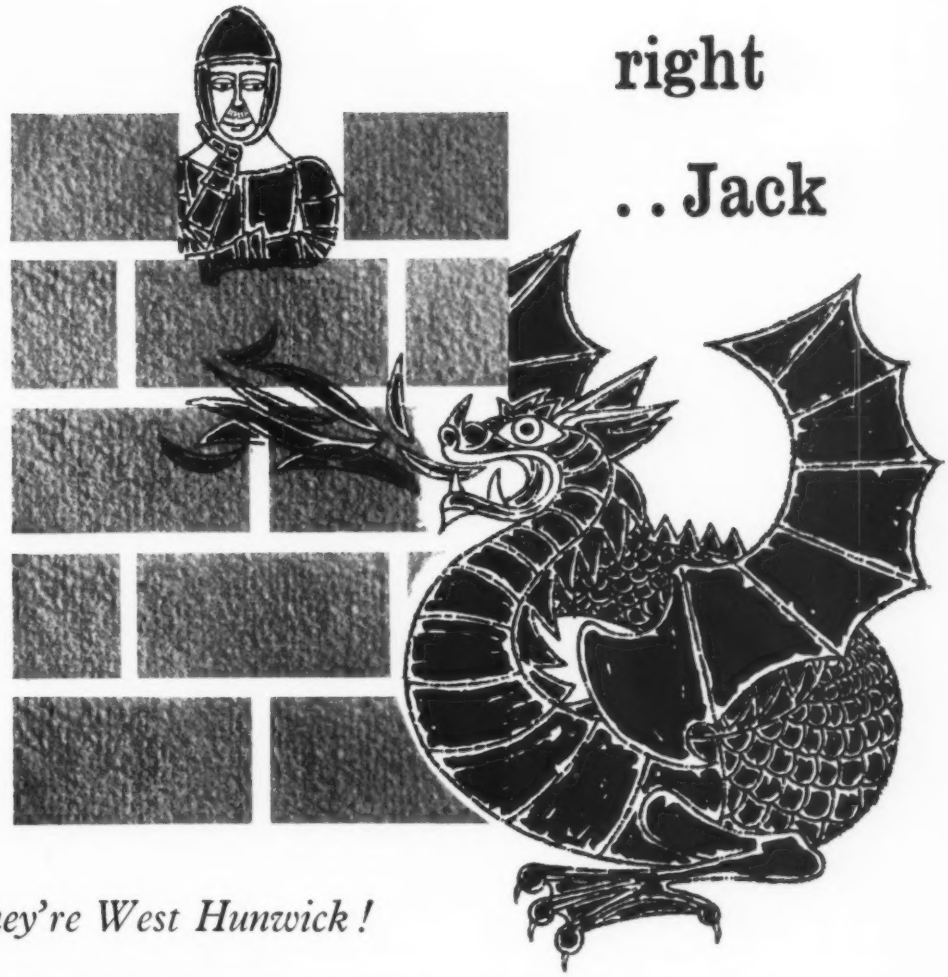


L.C.38.

I'm all right .. Jack



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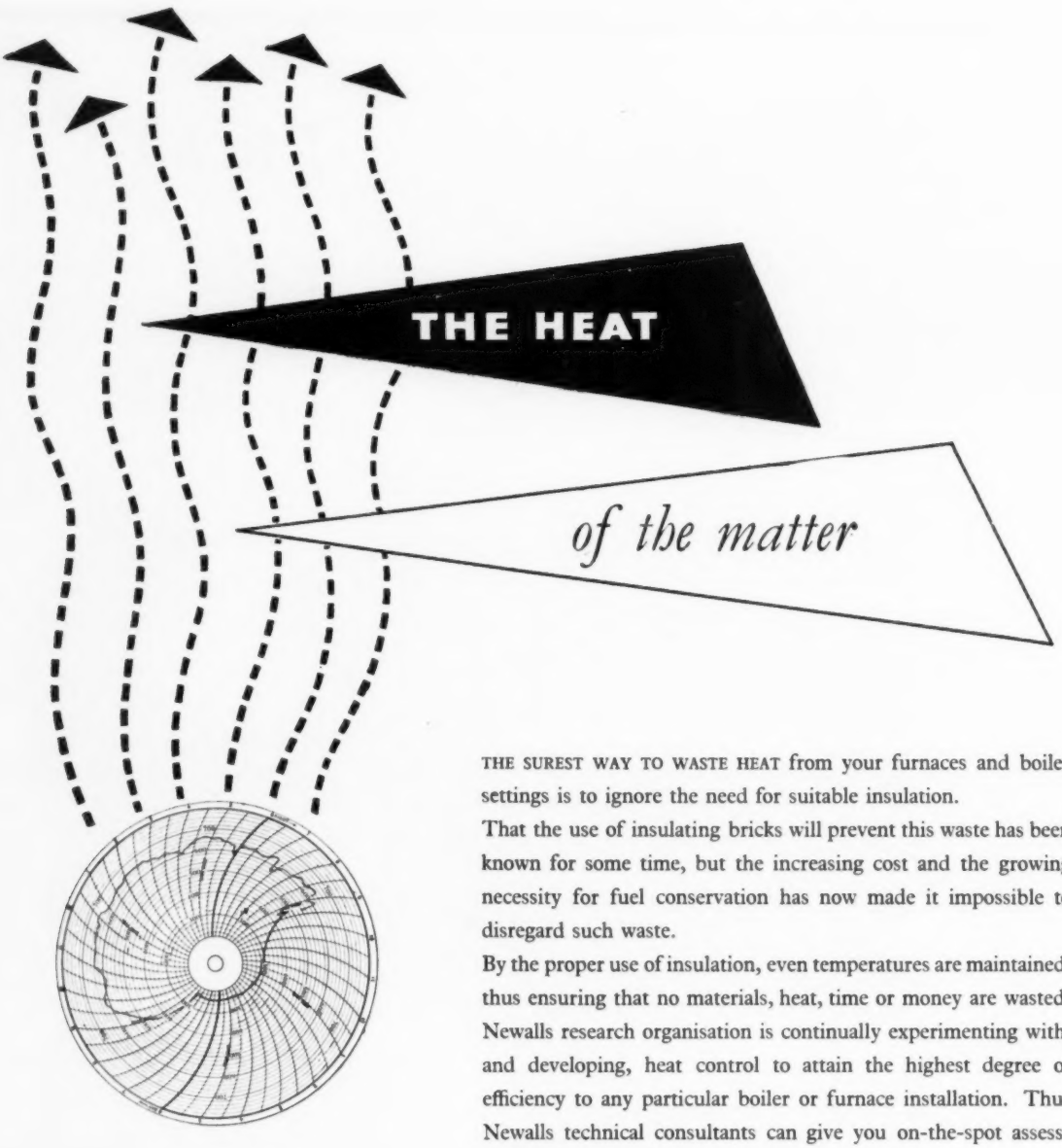

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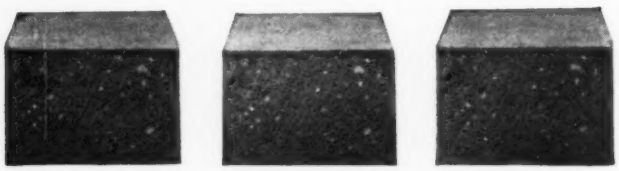

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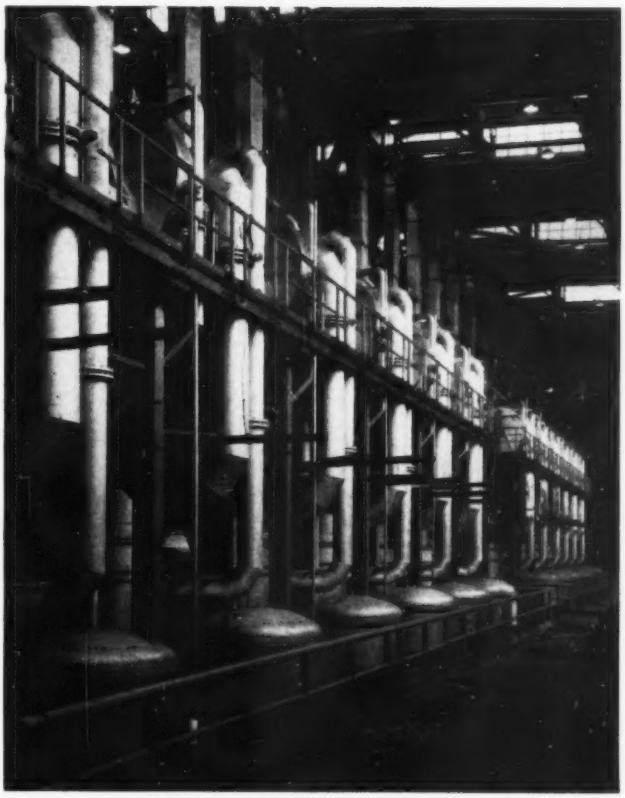

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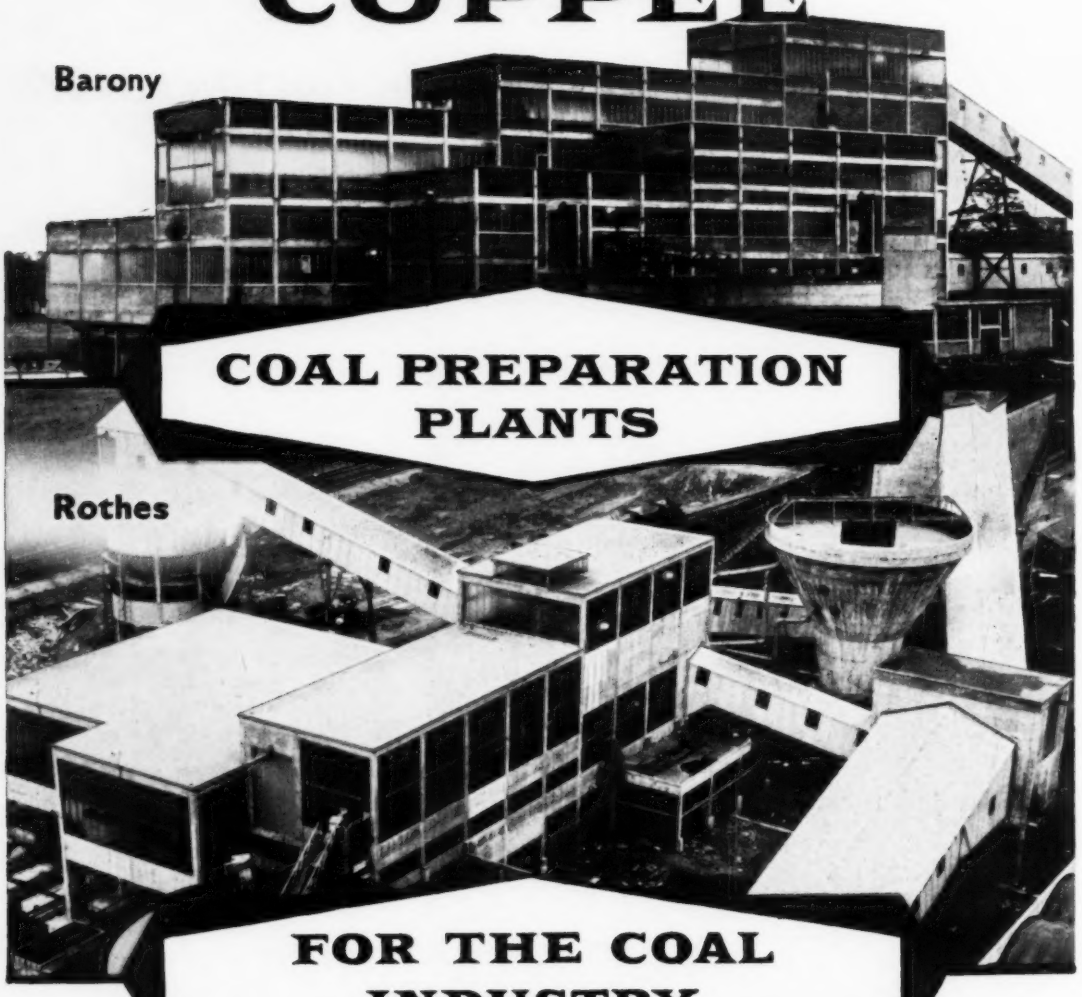

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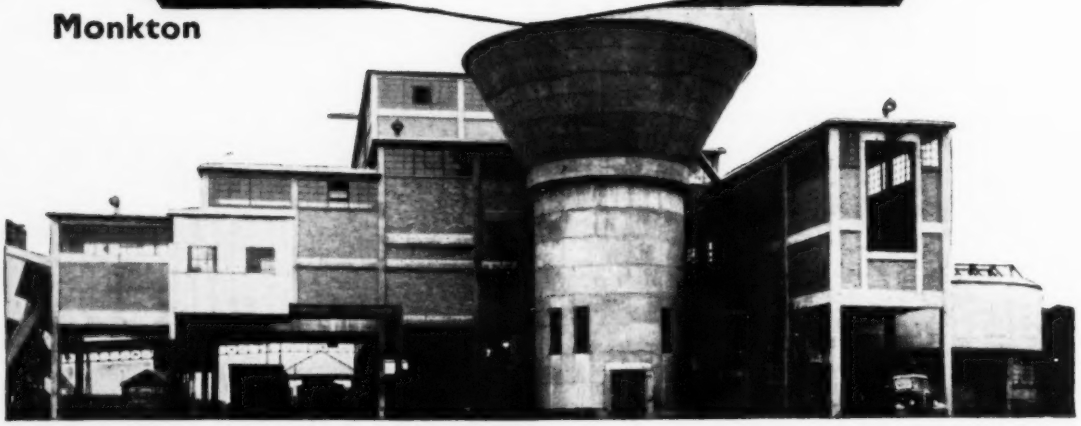

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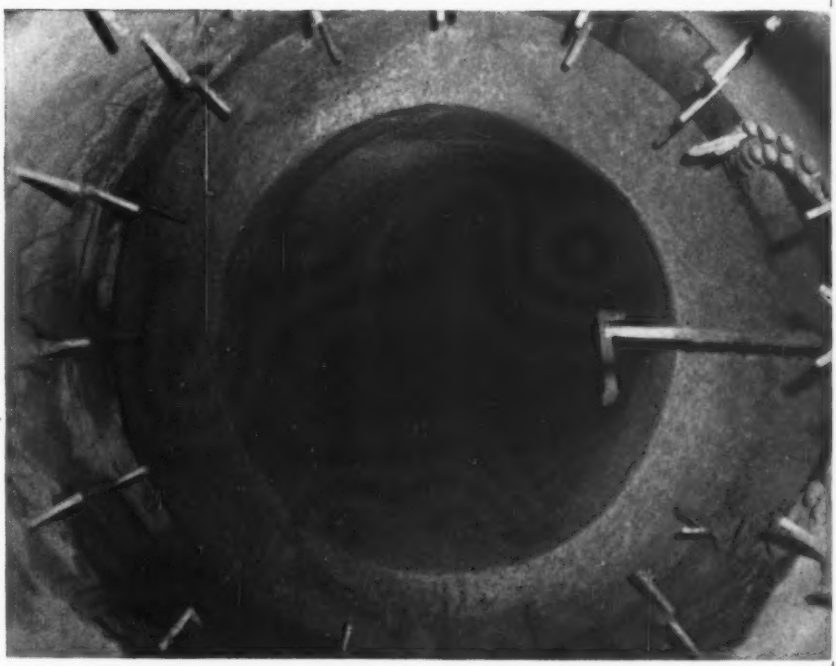
THIS IS ---------- ? ----------

1 . . . AN EXTENSION TO THE LONDON UNDERGROUND

2 . . . THE BUSTLE MAIN OF A BLAST FURNACE

3 . . . THE INLET PIPE OF A HYDRO-ELECTRIC POWER STATION



Number two is the answer. It is in fact the bustle-main of the Queen Victoria blast furnace at Appleby-Frodingham in course of being lined with Tri-Mor 'Guncrete'. The main is 5 ft. in diameter and the 'Guncrete' lining 9" thick. This is a far quicker and cheaper form of lining for a hot-gas main than brickwork. After twelve months continuous service this lining is still in perfect condition. Brick-lined mains usually require considerable repair after this period.

Tri-Mor 'Guncrete' is one of a series of new mouldable and castable refractories which are reducing first costs *and* maintenance costs in every kind of furnace from forging furnaces to ships' boilers. The most useful of these refractories are: - - - - - - - - - - - ->

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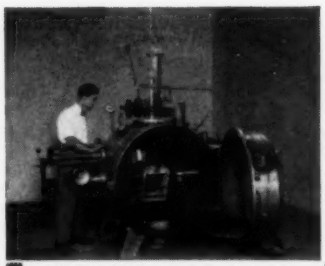
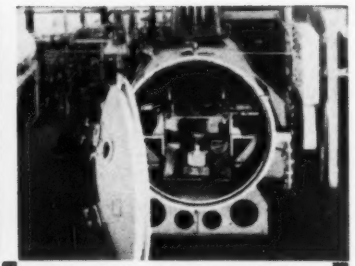


Model 2555 Vacuum Induction Furnace with melting capacity of 50 pounds of steel. Other standard furnaces have capacities of 12 to 3,000 pounds.



Model 2705 Non-Consumable Arc Skull Furnace with a capacity of 50 pounds of titanium. Other standard vacuum arc furnaces have capacities of 8 to 10,000 pounds of titanium.

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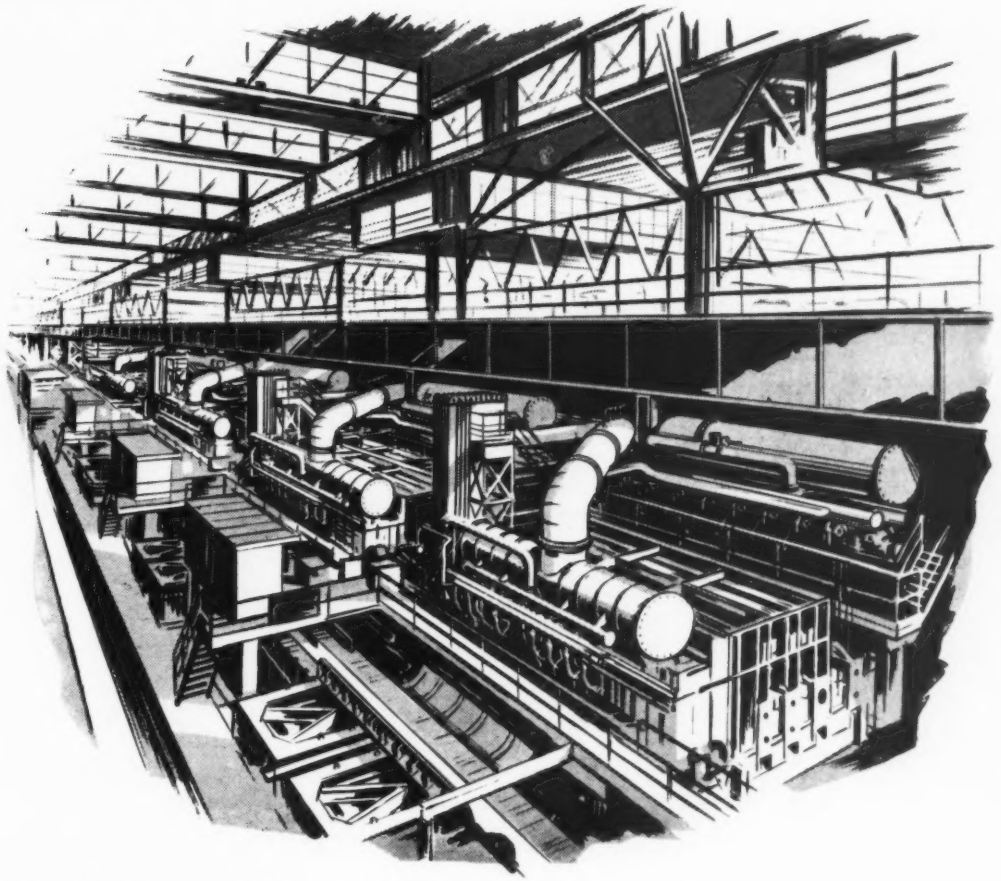

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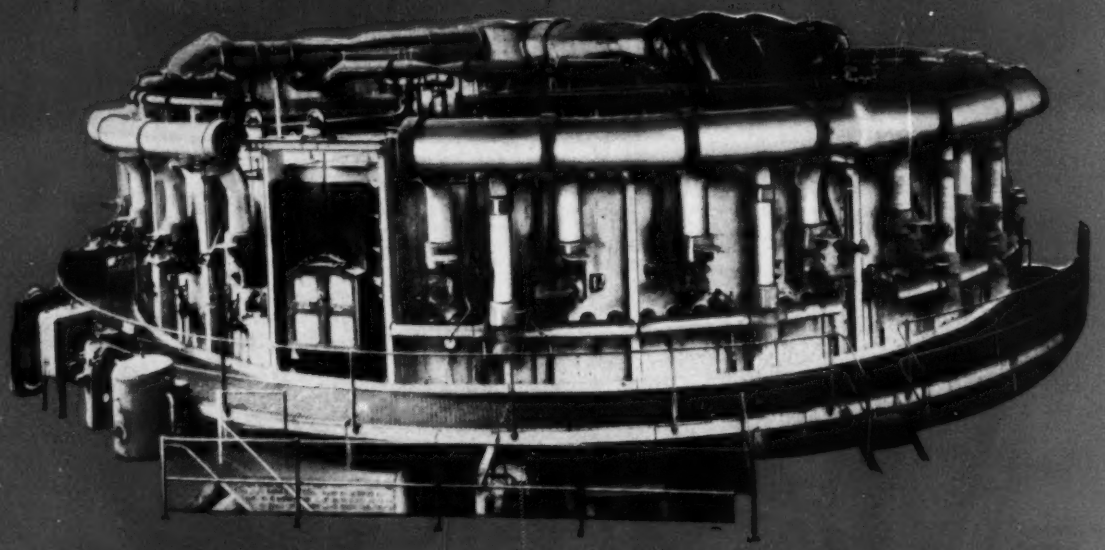

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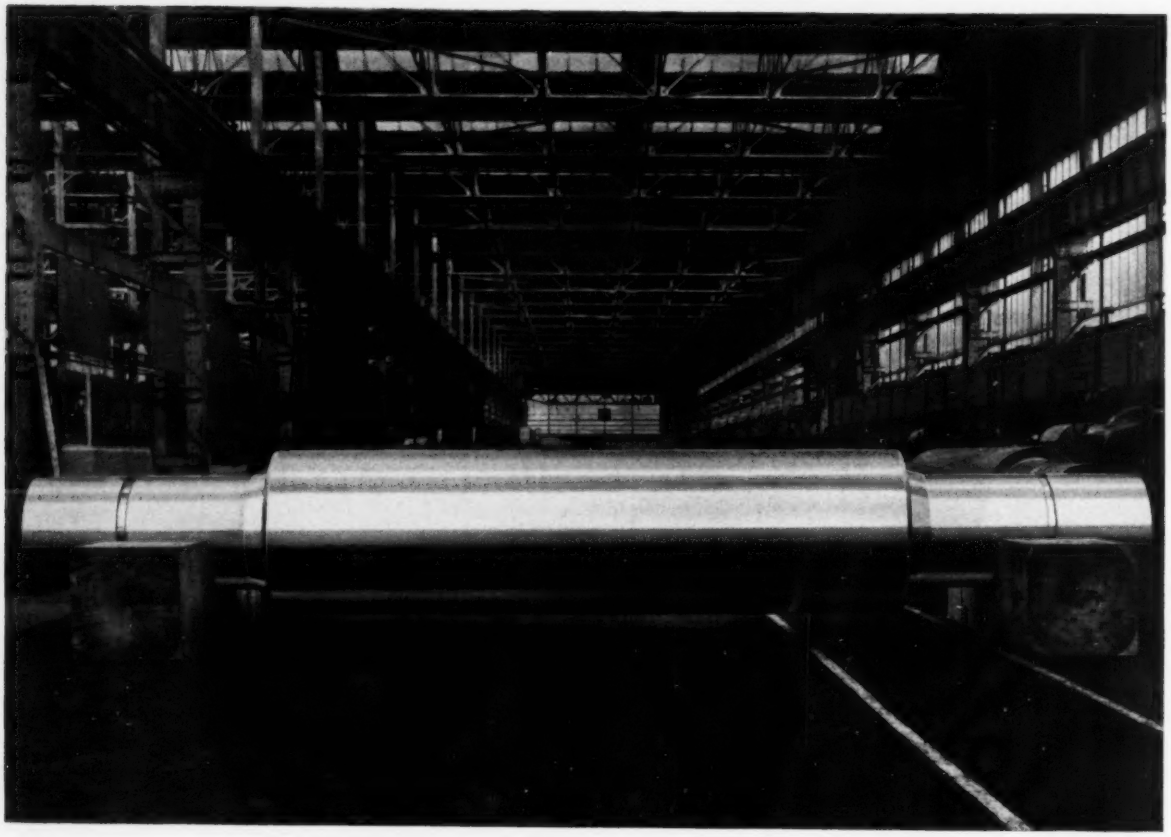

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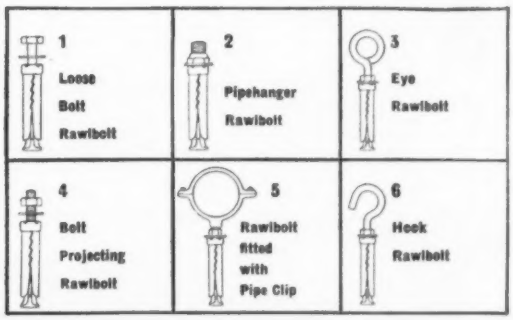

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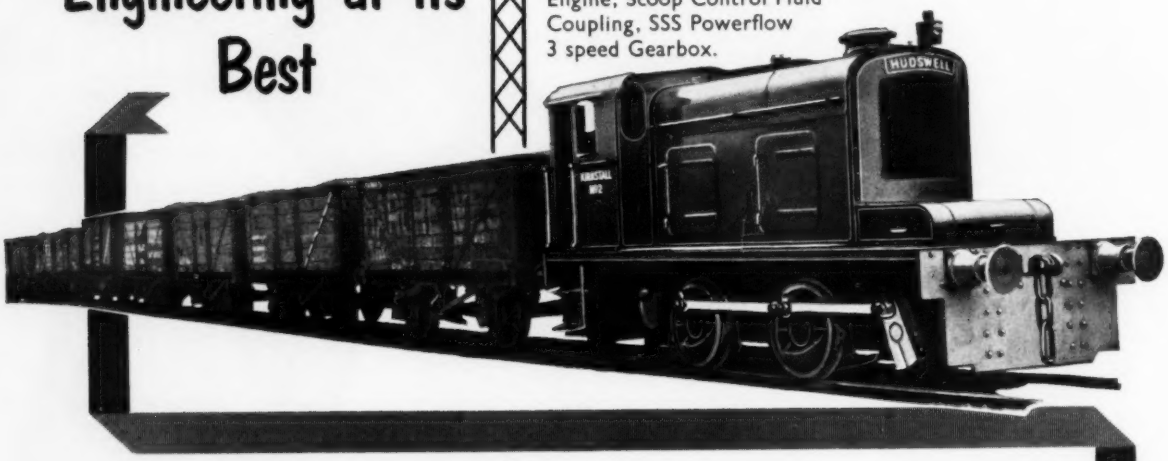

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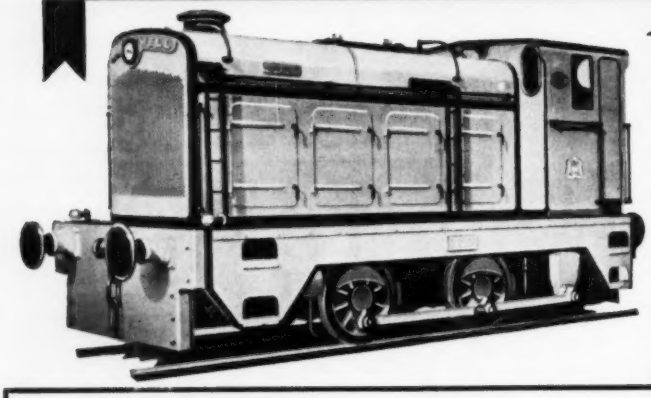

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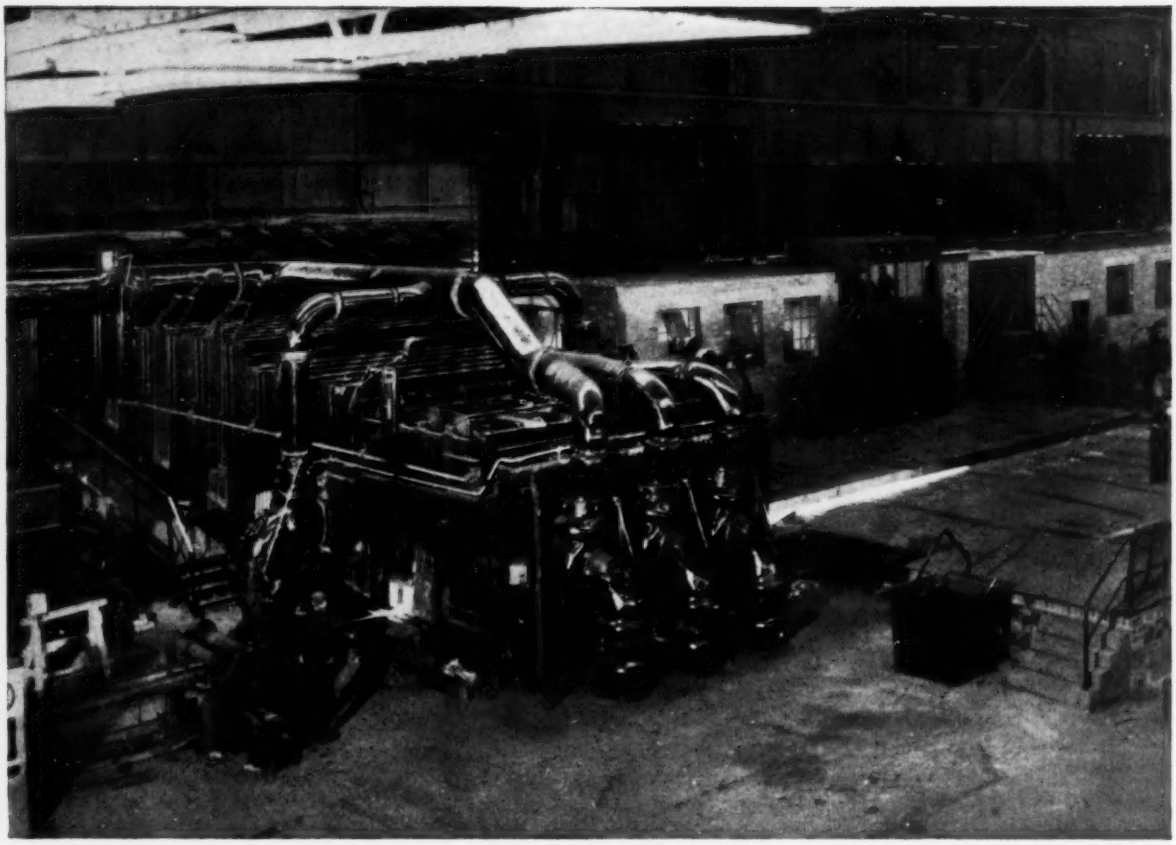

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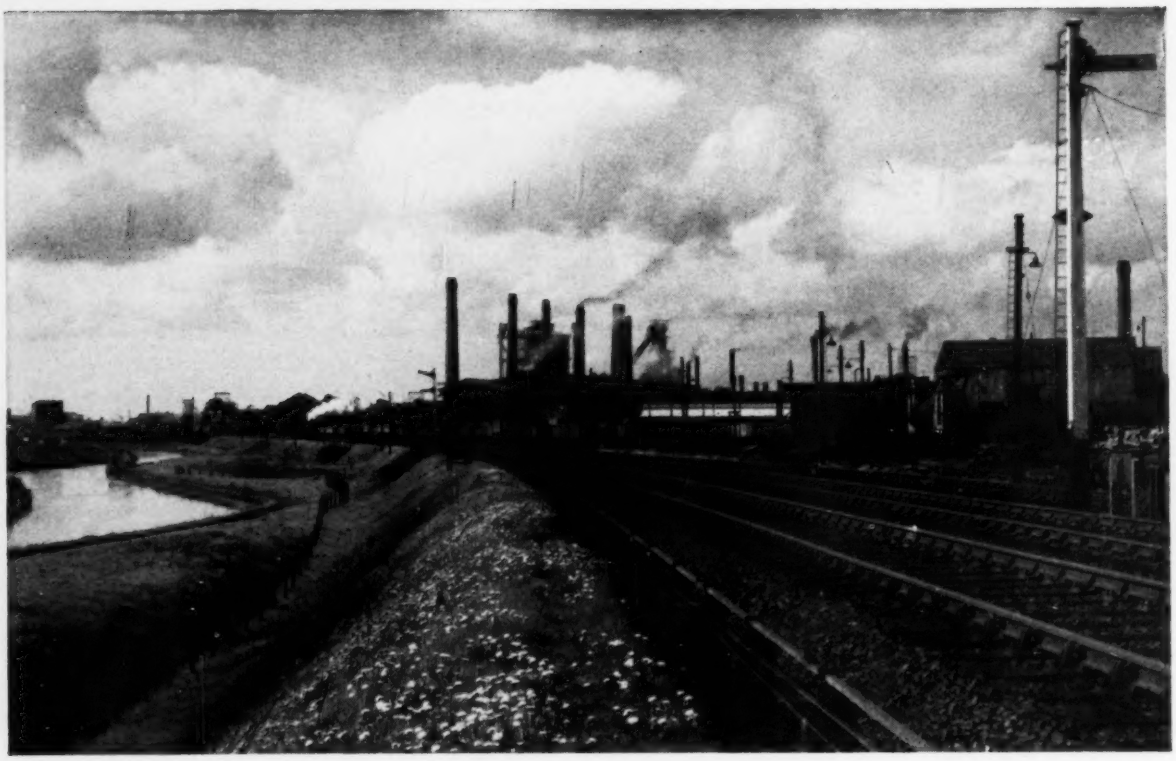

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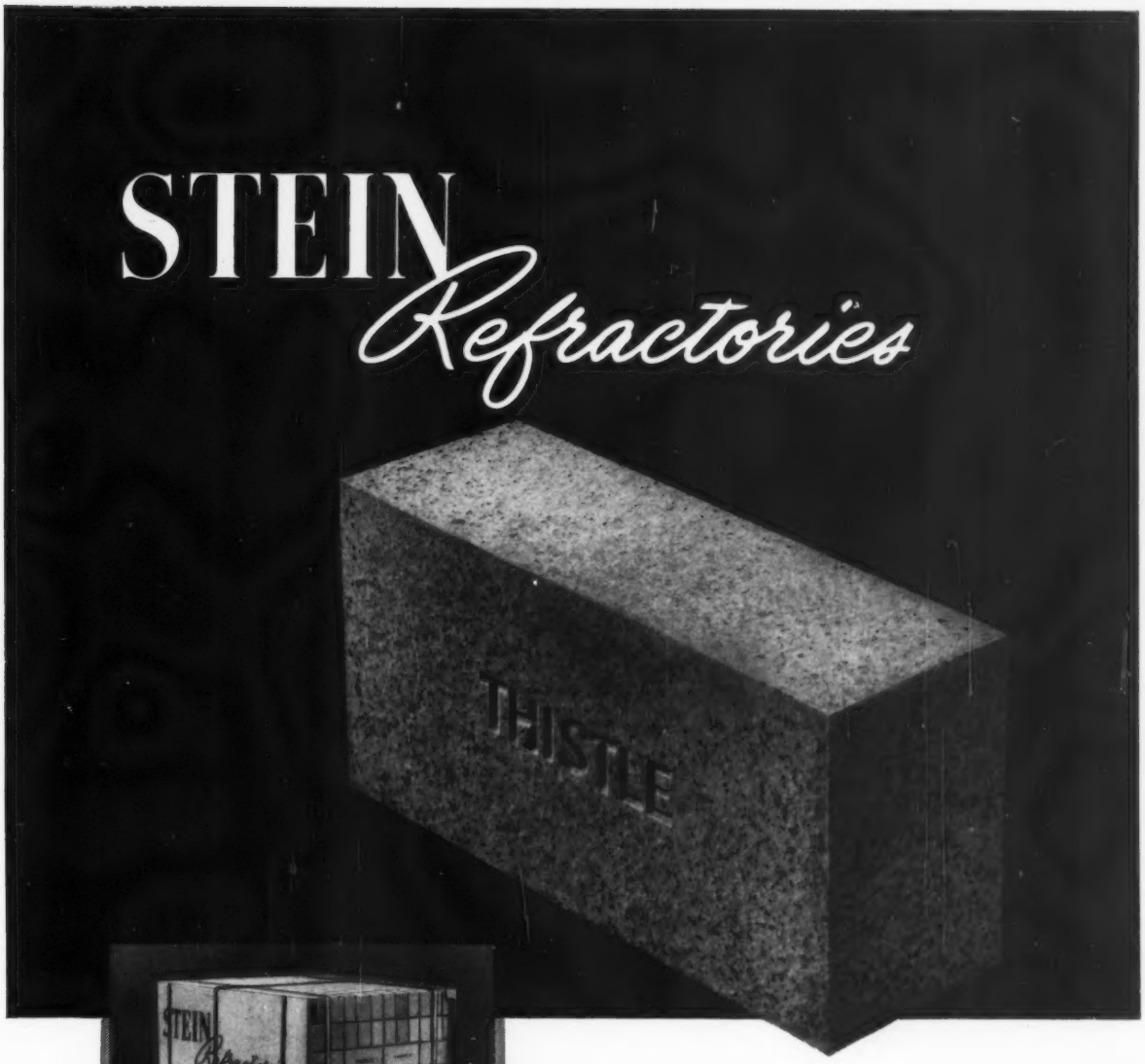

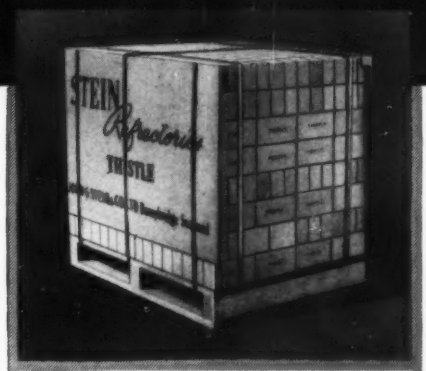

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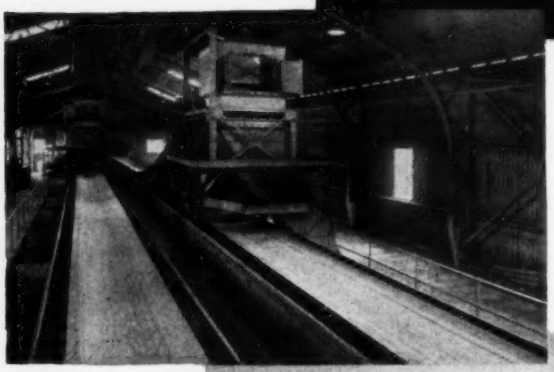

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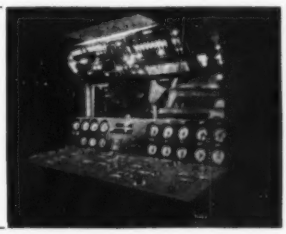
The feed rate control panel at Barrow



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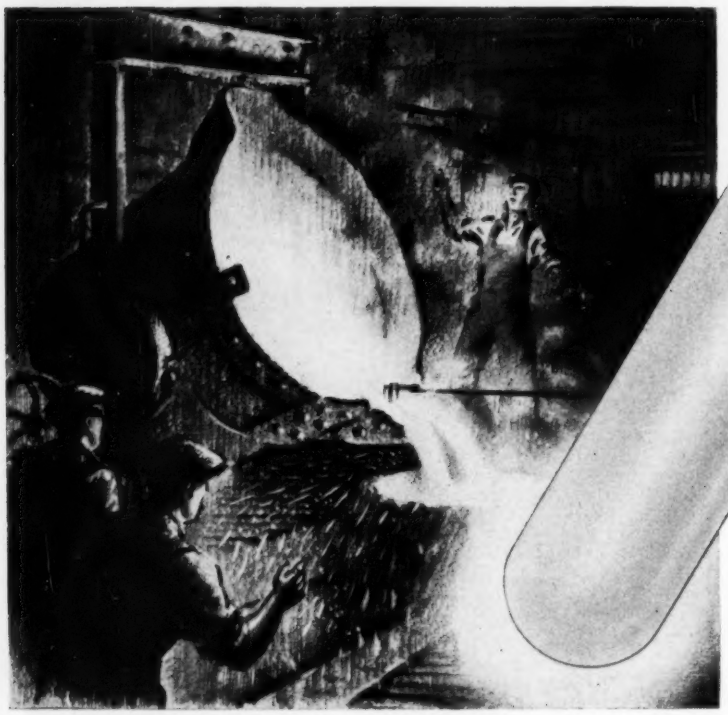

We also manufacture an extensive range of Vitreosil Laboratory Ware.

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Casting temperatures are *critical!* Vitreosil, pure fused silica, sheaths used in the Quick Immersion Thermocouple Technique have obviated erratic judgement of casting temperatures in modern steelworks and foundries all over the world. A single dip into the molten metal gives the true temperature in seconds.

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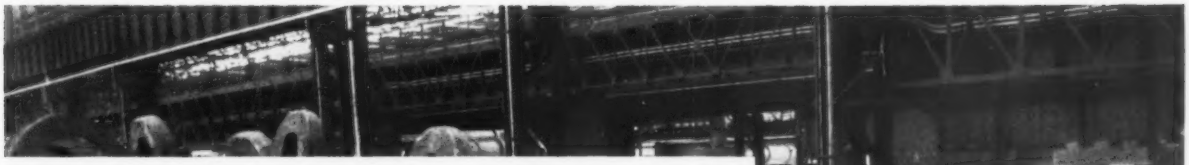
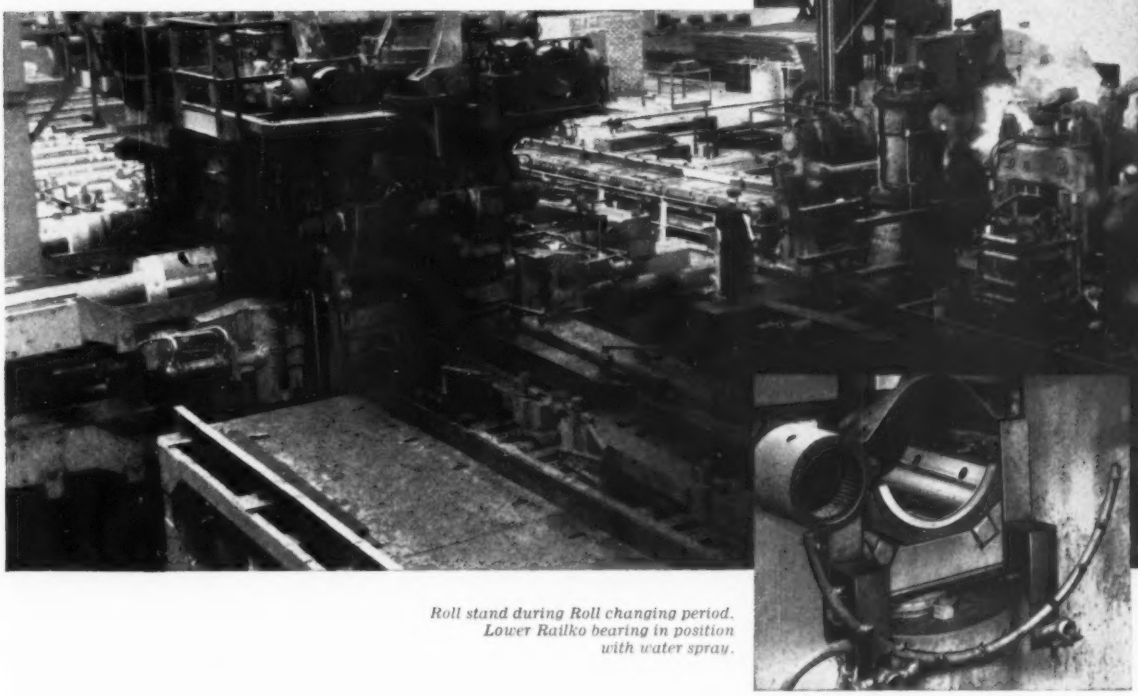


Railko Bearings at Lackenby—



Roll stand during Roll changing period. Lower Railko bearing in position with water spray.

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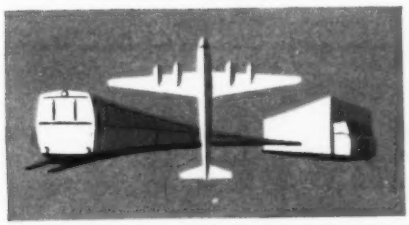
At the Lackenby works of Dorman Long – most modern in the world for the rolling of steel sections – the production of a new and wide range of beam and column sections opens up immense new possibilities for designers and constructional engineers.

In many places where extremes of temperature and pressure are met the performance of bearings of conventional materials would be unsatisfactory. To overcome these problems Railko bearings are specified and have proved completely suitable.

What are Railko bearings? . . . tough resin-impregnated fabric laminates specially moulded under heat and pressure to give specific properties, depending on the job.

Railko bearings have many advantages. They withstand extreme pressure and movement * have a high strength-to-weight ratio * a high compressive strength * a low co-efficient of friction * can be lubricated with a variety of fluids * in certain applications can be used without fluids * are resistant to acids and alkalis * have a low rate of wear * are easily machined * have excellent weathering properties.



Railko bearings are now widely used by manufacturers in the steel, railway, aviation, engineering and chemical industries. Perhaps they can help *you*? Write to us and we shall be glad to send you full technical details.

Railko bearings help every industry – **Land-Sea-Air**

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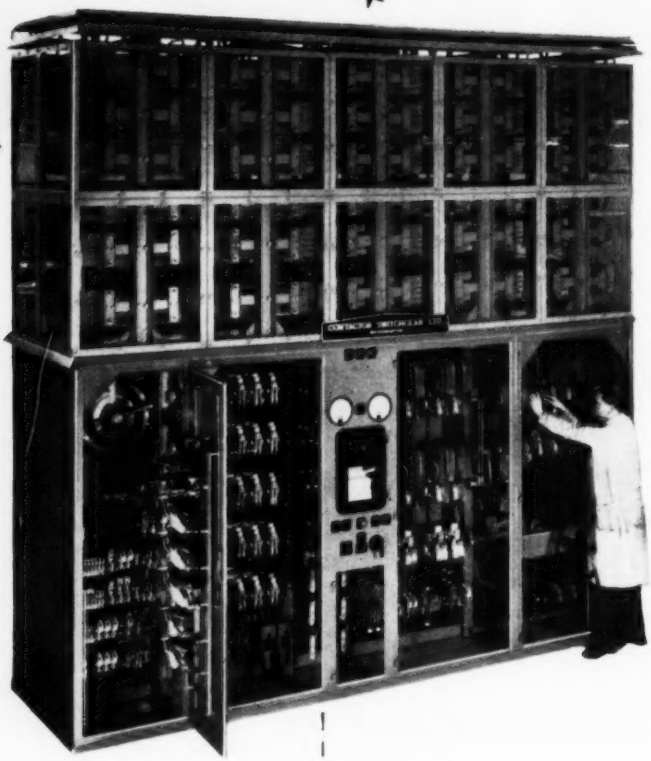
Control Gear for Steelworks Plant



The photograph shows a 2,300 H.P. 600 volts D.C. Shunt (Stability Compounded) motor control panel incorporating a motorised preset shunt field regulator, 'inch forward', 'inch reverse' features and emergency sustained dynamic braking for a "Cross Country" steel rod mill.

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May we have *your* enquiries for steel works automatic control gear?

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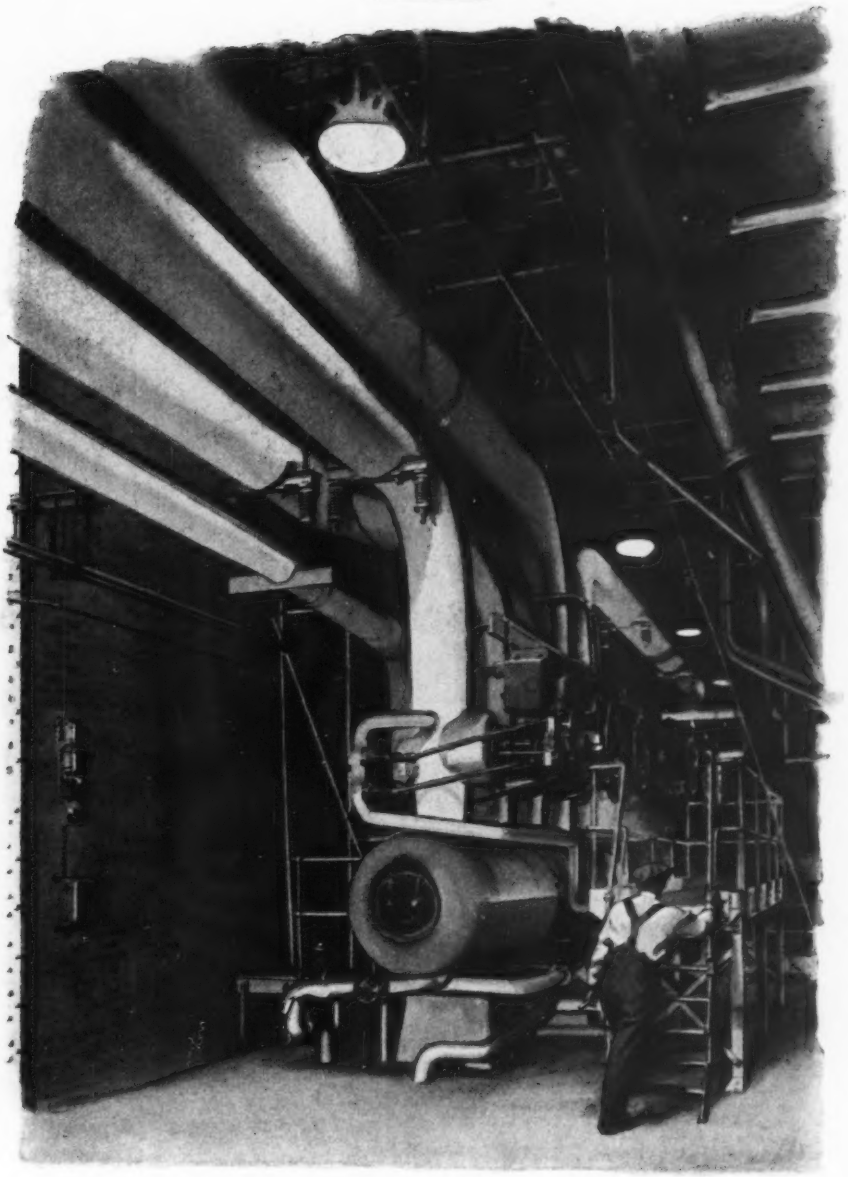

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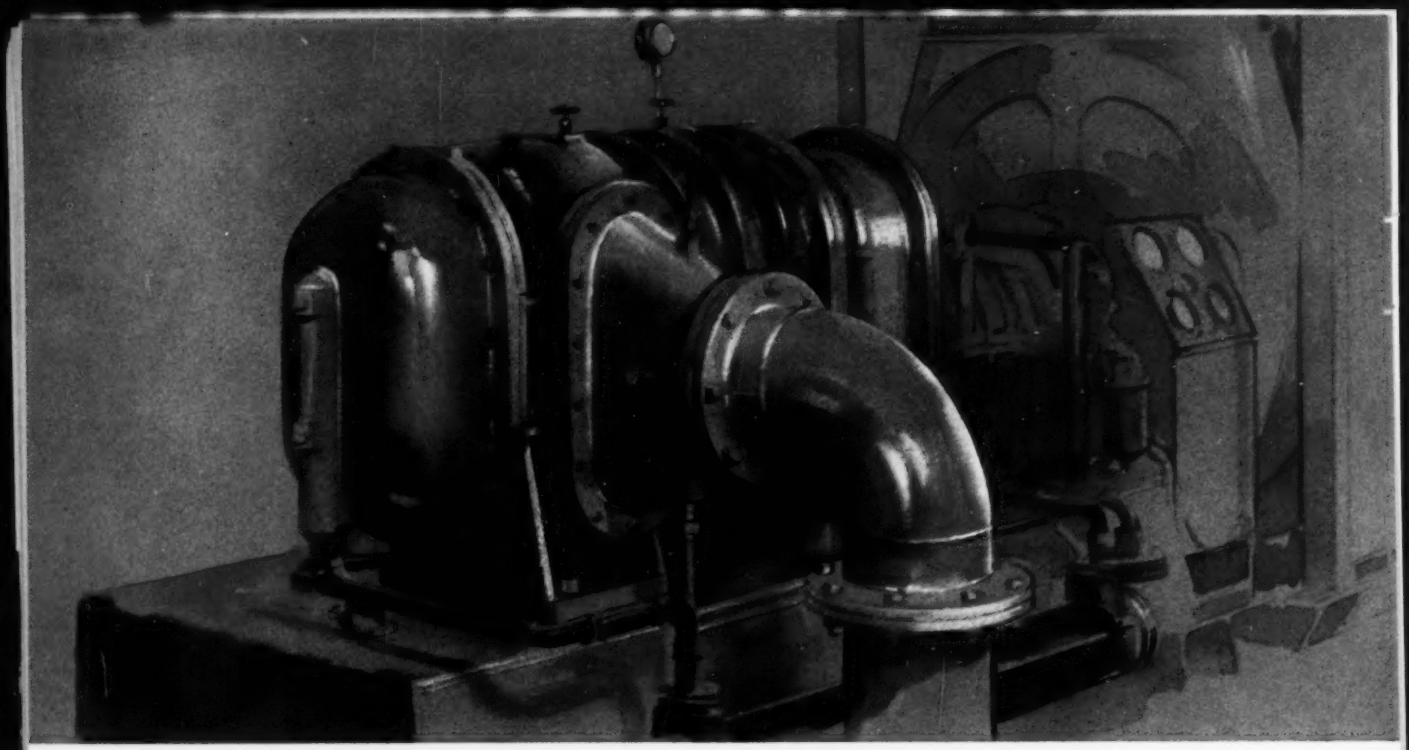

Howden compressor, capacity 3,500 c.f.m. (210,000 c.f.hr.) at 30 p.s.i.g.

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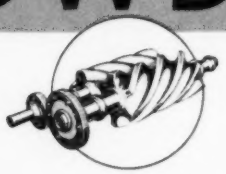
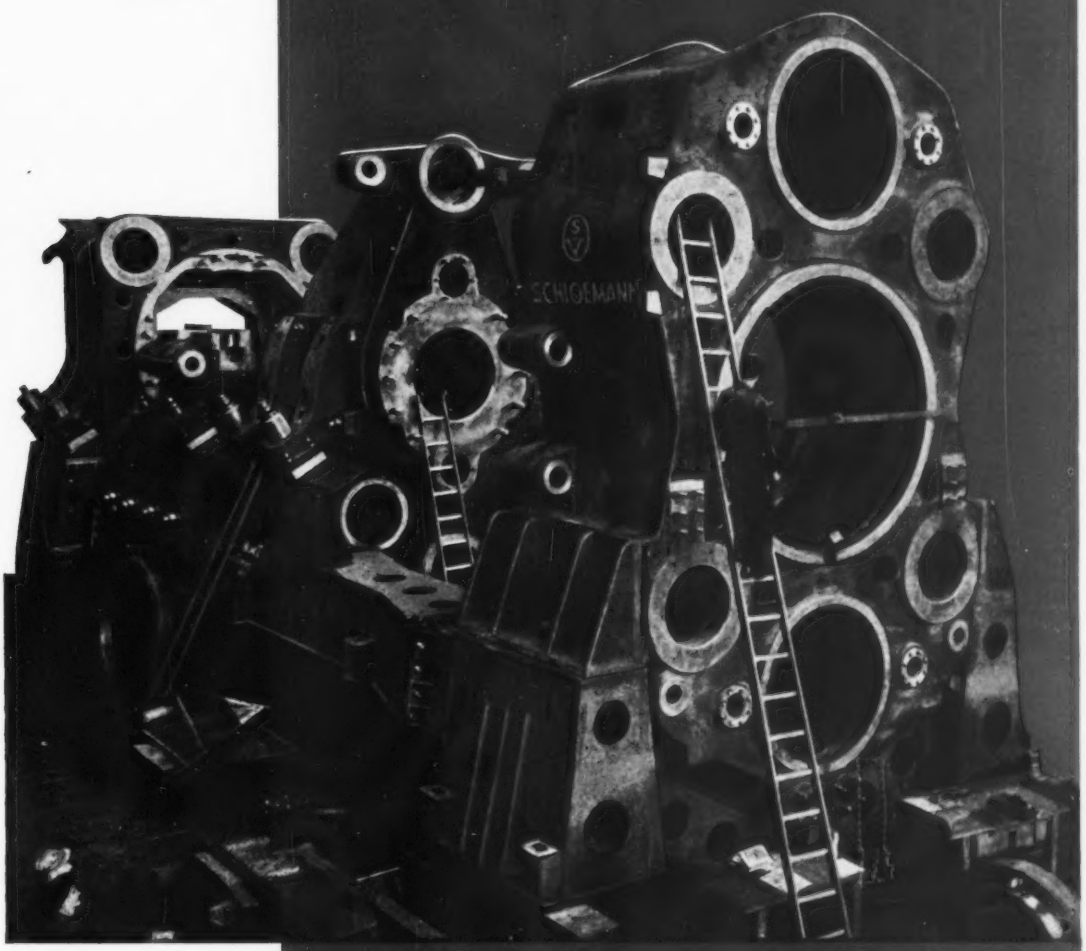


SCHLOEMANN



Another 14,000 ton Extrusion Press

About thirty years ago, SCHLOEMANN pioneered the concept of providing the light metal industry with giant presses. Designers were soon able to utilize forged and extruded pieces of sizes hitherto unobtainable and of low weight and high tensile strength. Thus, the prerequisites were created for new achievements in many fields. For example: On a SCHLOEMANN extrusion press for tubes and rods – the biggest in the world – aluminium billets up to 2.5 tons are extruded into sections for aeroplane construction, and these sections afford a saving in weight of up to 80 per cent compared with conventional sections fabricated by rivetting or welding methods. The picture shows a 14,000 ton extrusion press during erection in the shops. This is the second press of this size which has been built by SCHLOEMANN for Aluminum Company of America.

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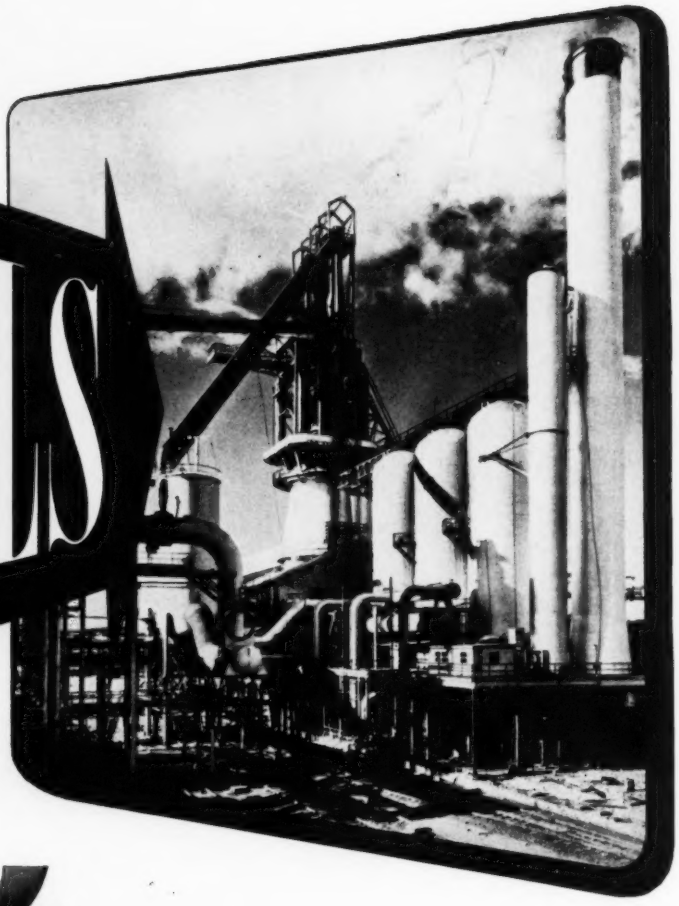

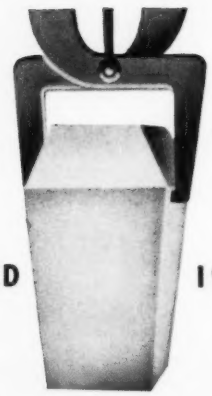

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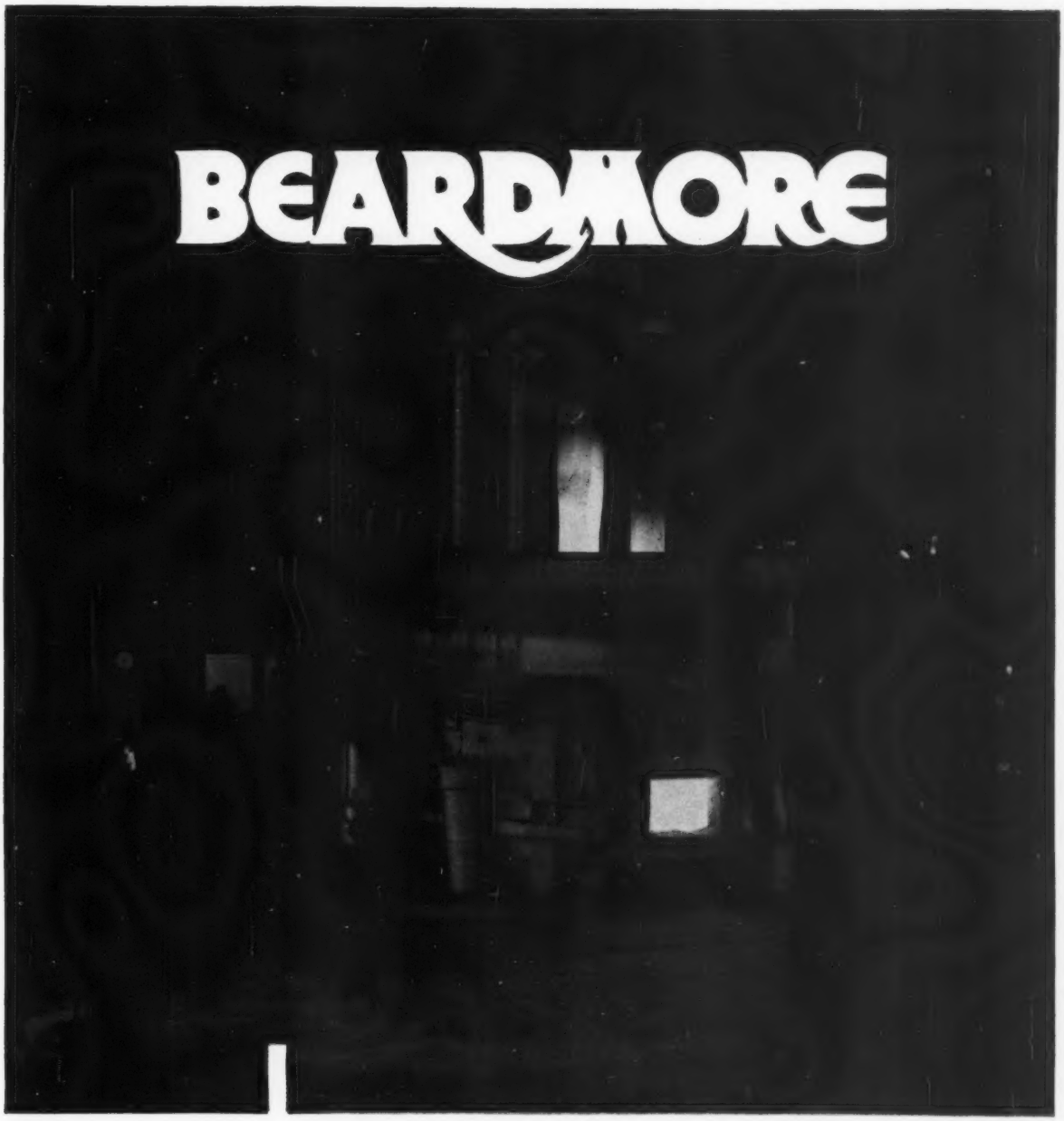

Among the latest developments at Parkhead Steelworks, Glasgow is the 80-ton Electric Arc Melting Furnace shown above.

Forgings and Castings up to 150 tons in Carbon and Alloy steels, including Boiler Drums, Forged Steel Fully Hardened Work Rolls, Forged Steel Solid and Composite Back-up Rolls, Heavy General Engineering Plant and complete machining facilities.

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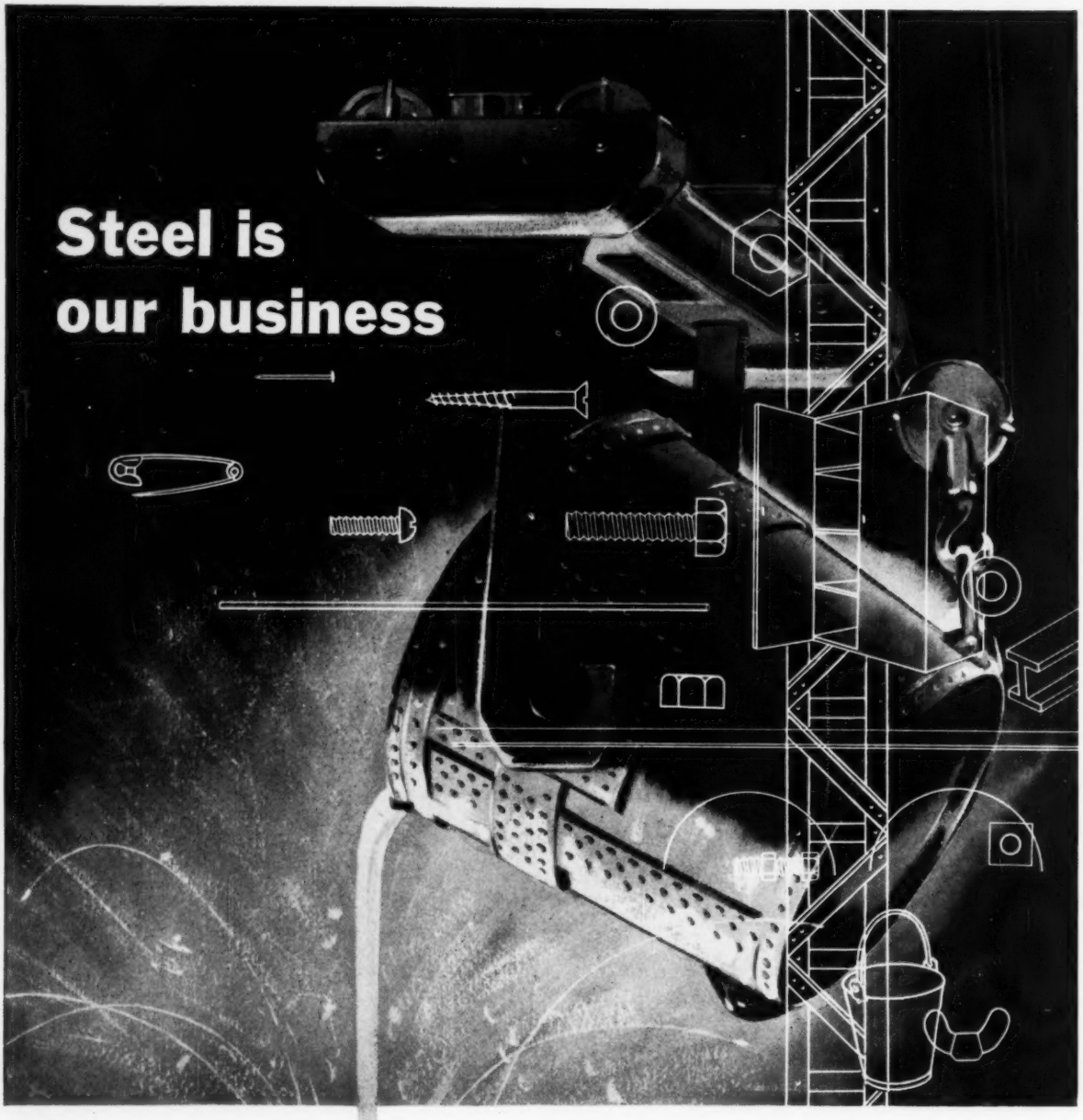

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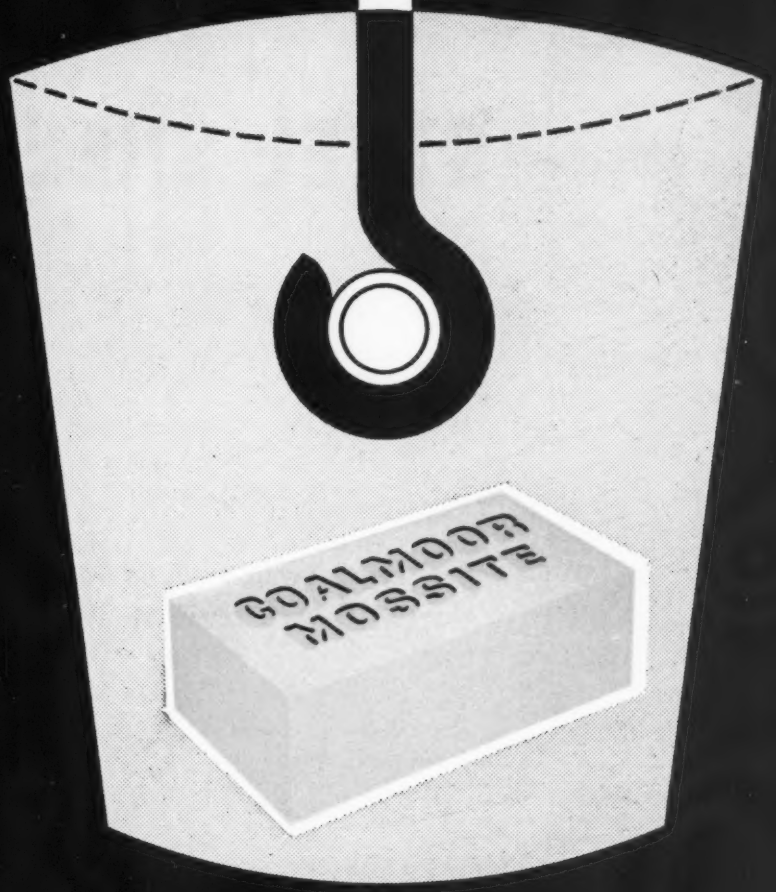
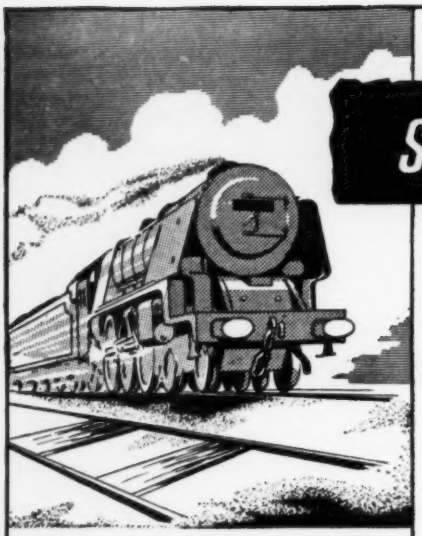
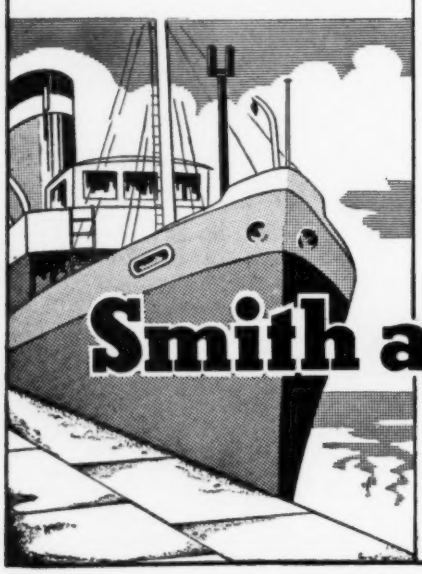
in the lead...



COALMOOR MOSSITE

COALMOOR REFRACTORIES (HORSEHAY) LTD. Lightmoor, Dawley, Shropshire





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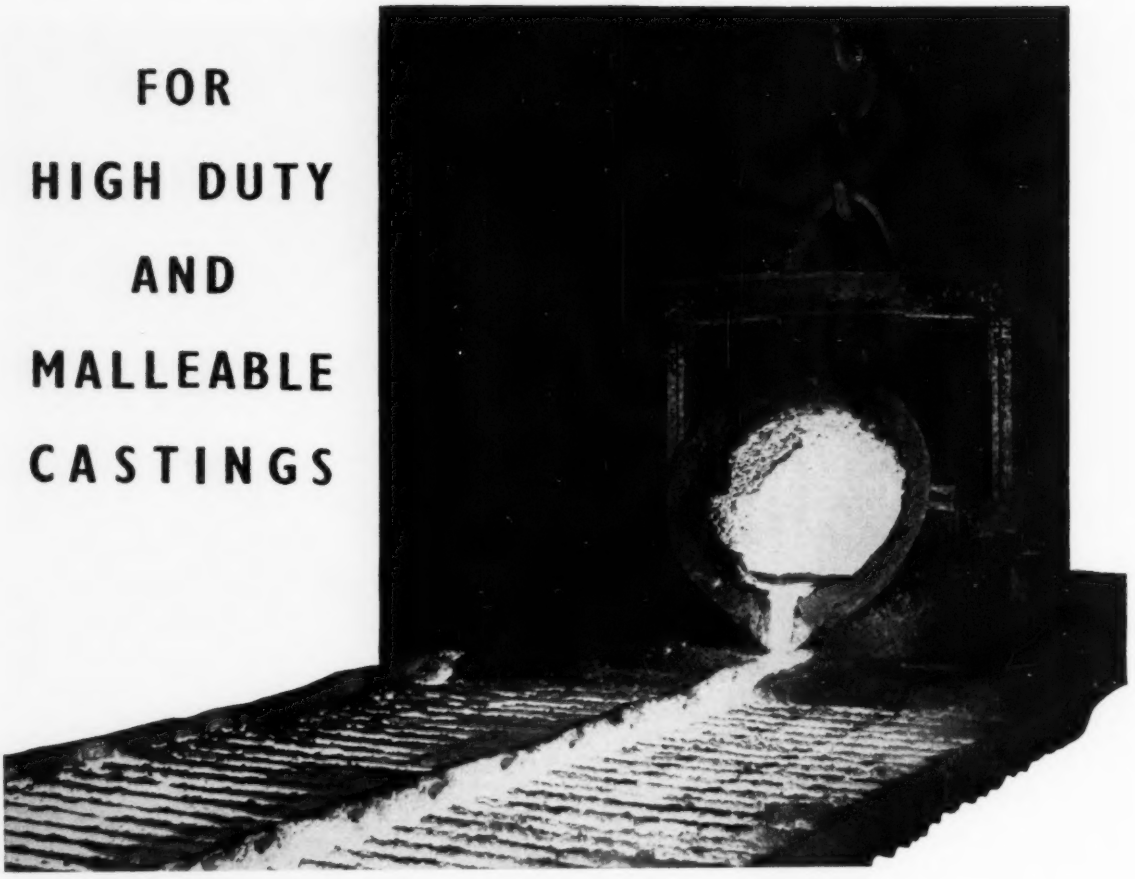

The seven standard grades of Stanton Dale Refined Pig Iron

GRADES:	A	B	C	D	E	F	G
SILICON %	1·9–2·1	1·4–1·6	0·9–1·1	2·25–2·5	0·9–1·1	1·4–1·6	1·9–2·1
SULPHUR %	0·06	0·07	0·08	0·05	0·08	0·07	0·06
PHOSPHORUS %	0·6–0·7	0·6–0·7	0·6–0·7	0·4–0·5	0·25	0·25	0·25
MANGANESE %	0·8–1·5	0·8–1·5	0·8–1·5	0·8–1·5	0·8–1·5	0·8–1·5	0·8–1·5
TOTAL CARBON %	2·7–3·0				2·8–3·1		

In addition to the above other grades of Dale Refined Iron can be supplied to meet more exacting demands which call for alloy additions and special processing.

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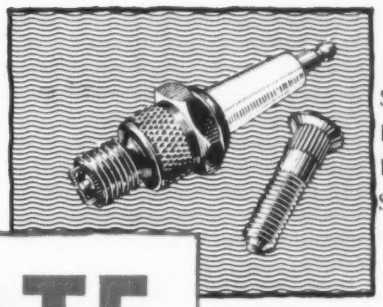

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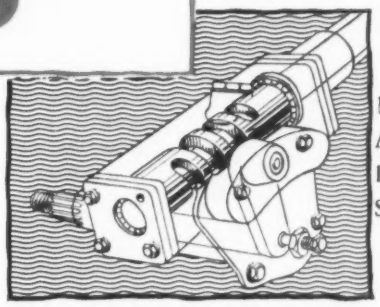

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RANGE OF QUALITIES

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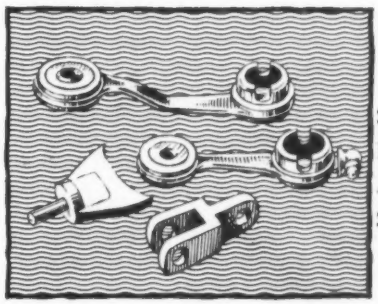

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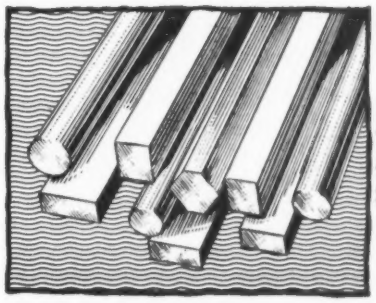
Rounds $\frac{3}{8}$″ to $\frac{39}{64}$″ in 500 lb. coils.
Rounds $\frac{5}{8}$″ to $1\frac{1}{16}$″ in 900 lb. coils.
Hexagons $\frac{3}{8}$″ to $\frac{9}{16}$″ in 500 lb. coils.
Hexagons $\frac{27}{64}$″ to 1″ in 900 lb. coils.
Coils may be split if required.

COLD FORGING QUALITY WIRES

0.240″ to 0.550″ in 500 lb. coils.
0.550″ to 1.000″ in 900 lb. coils.
Coils may be split if required.



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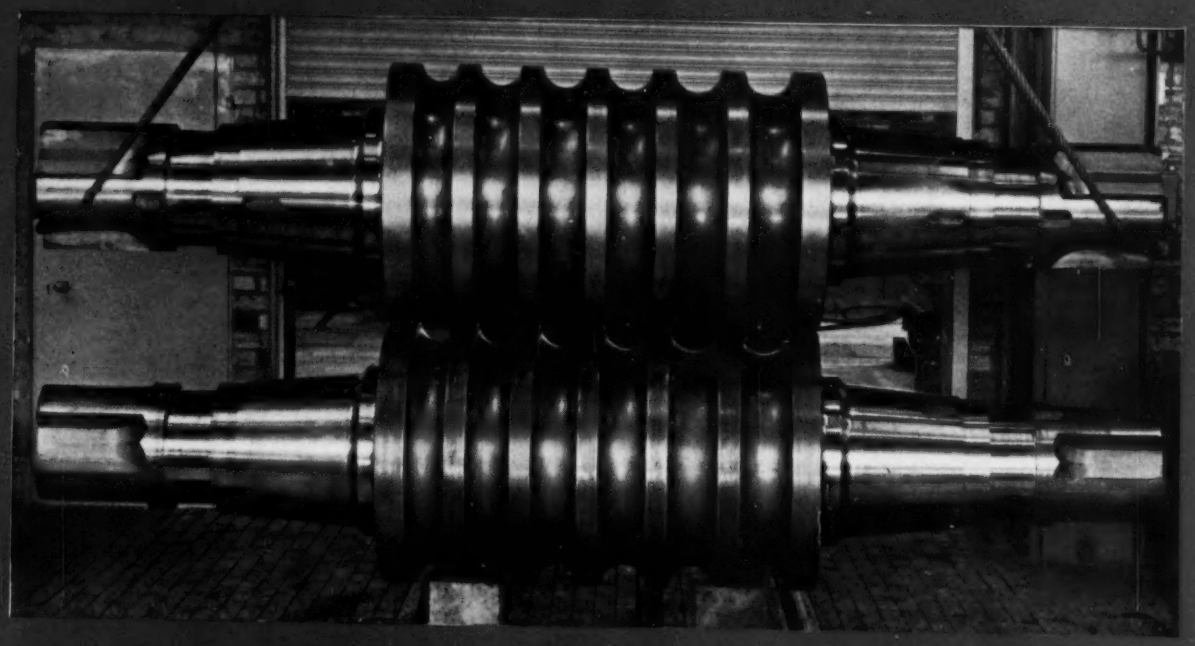

A pair of our Special "SSXH" Mooralloy Quality Rolls for Finishing Large Rounds 4½" to 6" dia. for No. 6 Stand. Roll size 32" dia. x 54" long barrel.

The Specialised Products include:

CHILL AND ALLOY CHILL ROLLS FOR HOT & COLD ROLLING ALL CLASSES OF STEELS FOR SHEETS, STRIP SECTIONS,
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ALSO THE S.G. RANGE OF SUPER TOUGH SPHEROIDAL GRAPHITE ALLOY IRON ROLLS

No. 5 Vertical Edging Stand in our Mooralloy "SSXM" Quality for Billet train (diamond pass) Leader for 2" to 4" Billets. Roll size 31½" dia. x 18" long barrel.

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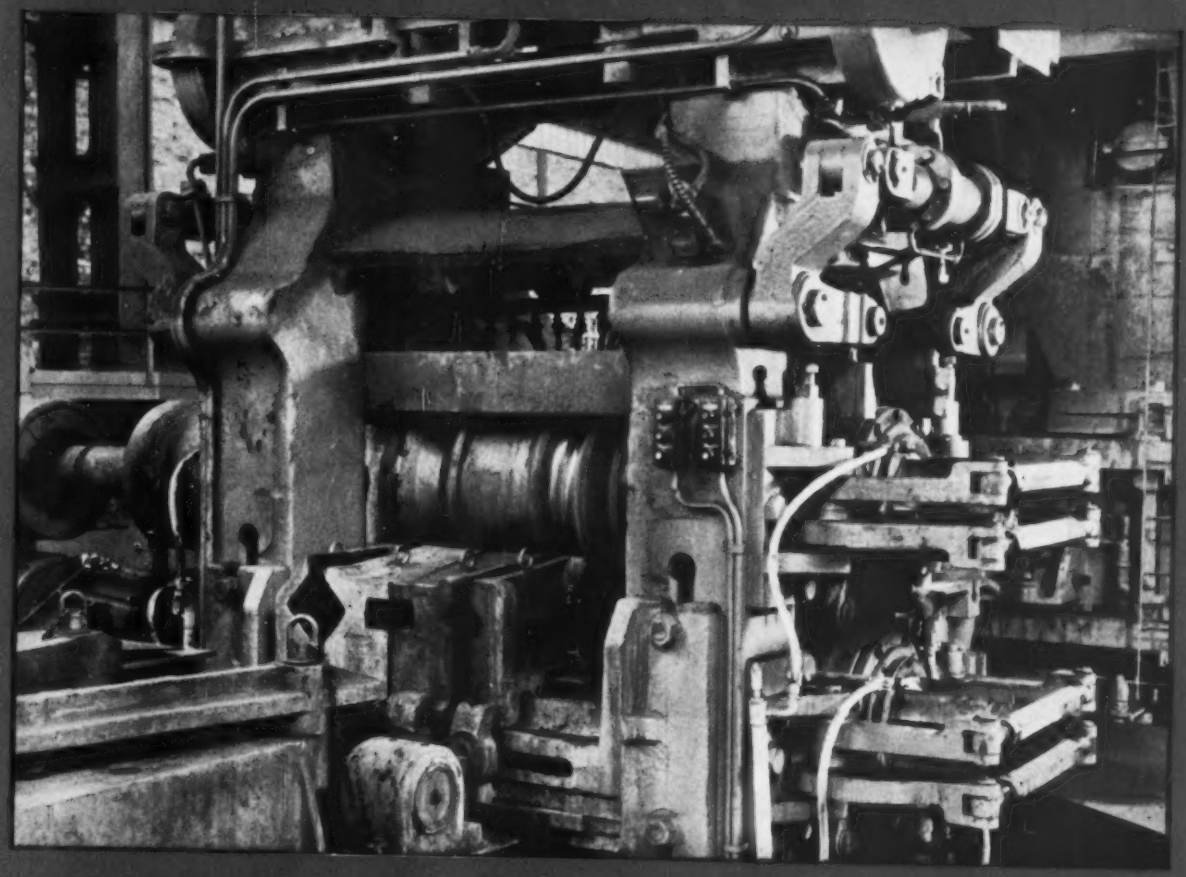

No. 6 Stand Finishing for 4", 4½" and 5" Billets, also Roughing for 2" to 3½" Billets and Slabs at Consett Iron Co., Ltd., showing our Special S.S.X. Mooralloy Quality Rolls. Roll size 32" dia. x 54" long barrel.

Photographed by the courtesy of The Consett Iron Co. Ltd.

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The "XXL" and "XXXL" Ranges of Hard Superfine Close Texture Metal
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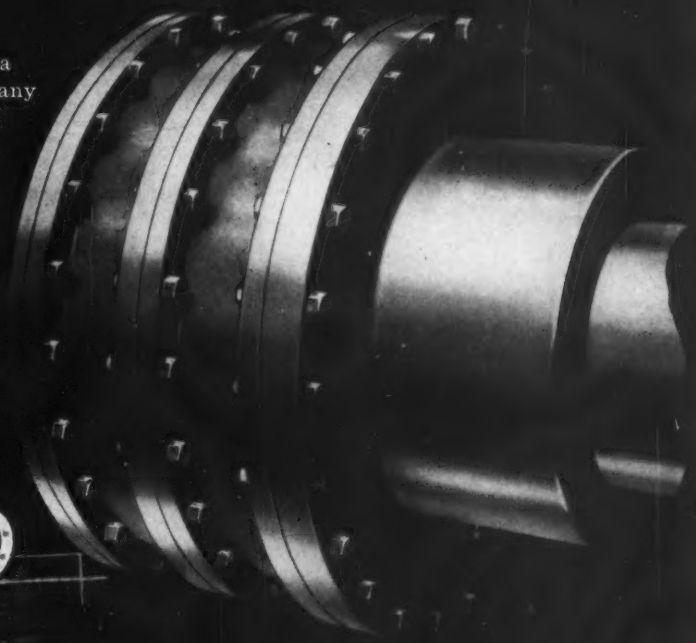

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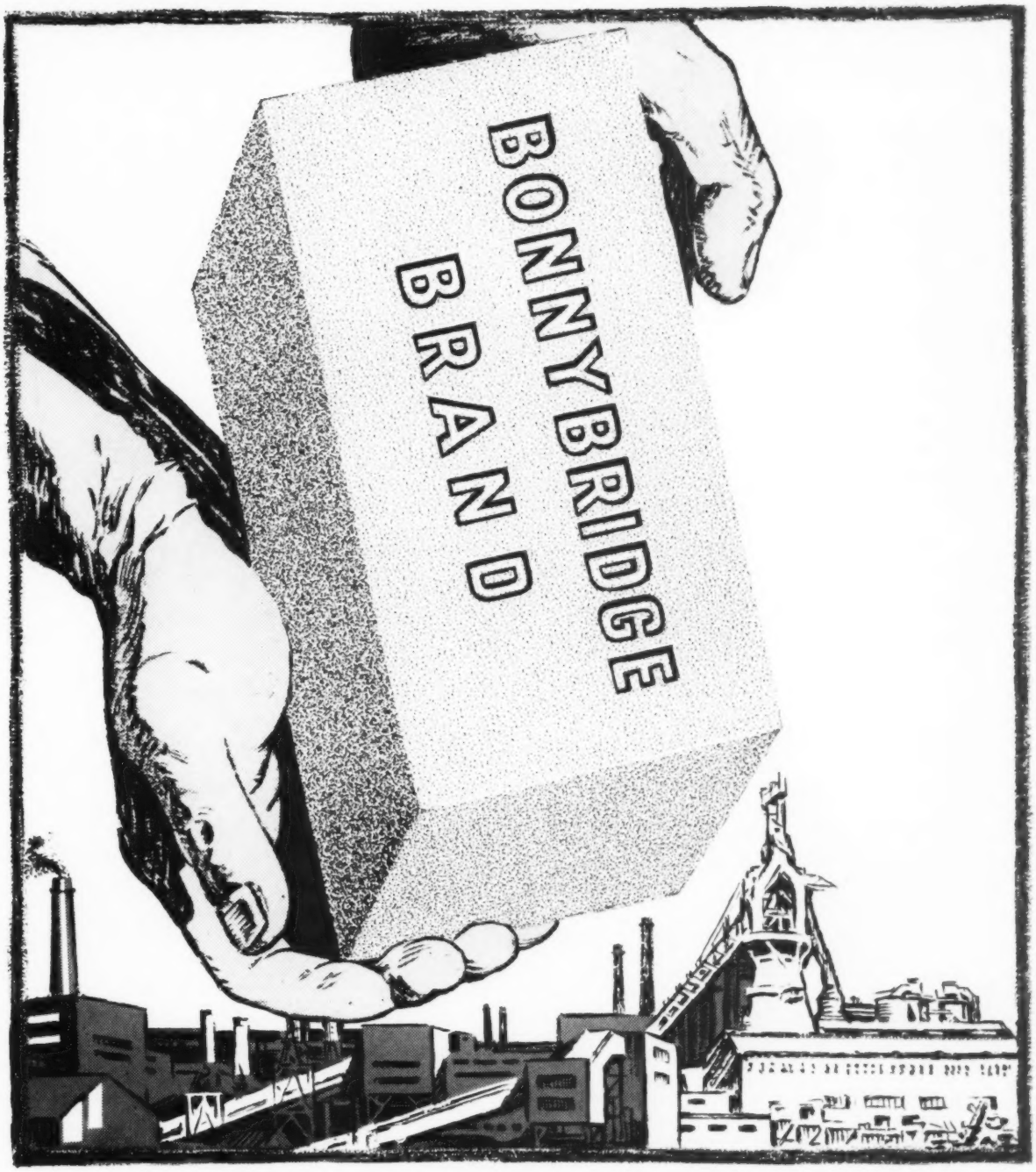

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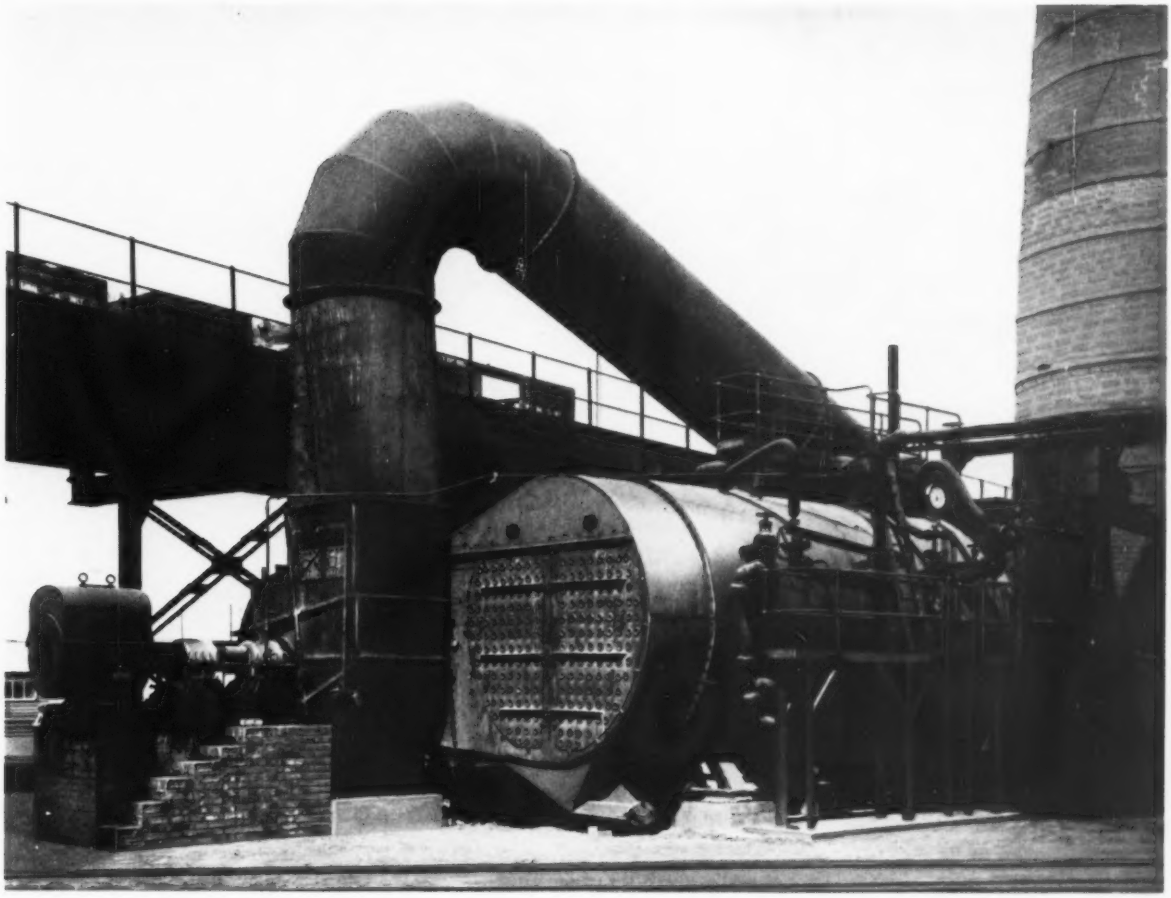

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Journal of The Iron and Steel Institute

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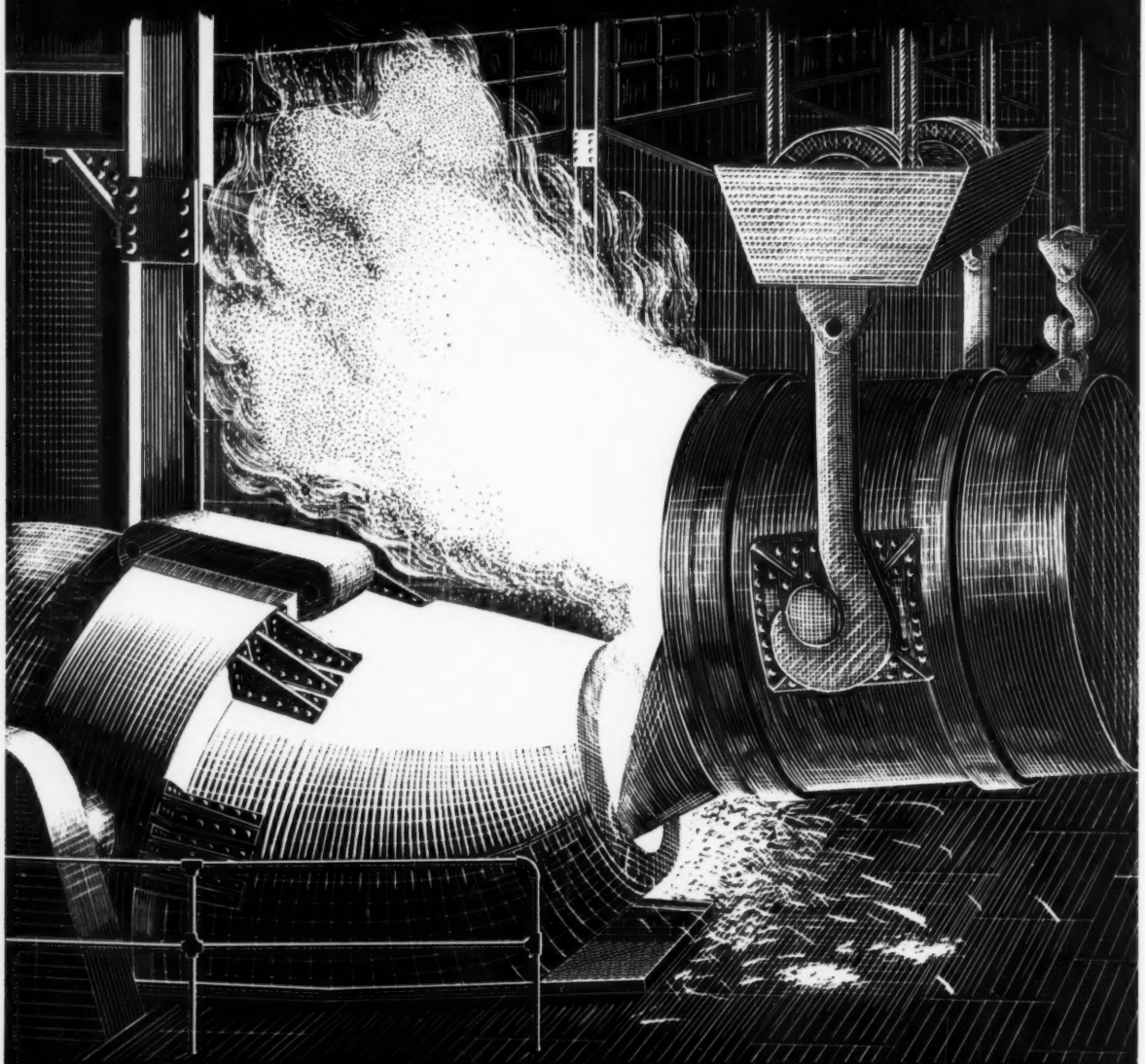

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BO KALLING

BO KALLING was born in Stockholm in 1892, and received his technical education at the Department of Metallurgy of the Royal Institute of Technology, graduating in 1915. From 1915 to 1916 he was employed by the Government Testing Institute at Stockholm. He first entered the iron and steel industry in 1916, when he joined Stora Kopparbergs Bergslags AB, working at the Domnarfvet iron and steelworks on the operation of electric reduction furnaces.

He left Stora in 1918 to join AB Ferrolegeringar at Trollhättan, carrying out research on ferro-alloys. In 1924 he moved to Avesta Jernverks AB, where he was engaged on research and development in the stainless-steel field. He returned to the Royal Institute of Technology in Stockholm in 1931 to become Professor of Ferrous Metallurgy, a chair he held until 1940, when he was appointed Director of Research and Development at Bolidens Gruv AB. In 1945 Professor Kalling was appointed Director of Research at Stora Kopparbergs Bergslags AB (Metallurgical Department), a position he held until his retirement this year.

Professor Kalling has been responsible for a great deal of very important research work during his long and distinguished career. Following his early work on stainless steels, he carried out important researches on the development of sponge-iron methods and steelmaking processes. He is best known for his studies of desulphurization and for the development of the Kaldo process for refining phosphorous pig iron in a rotating furnace with the aid of oxygen. In recognition of his contribution to the iron and steel industry he was awarded in 1957 the Jernkontoret Gold Medal with chain; he was only the seventh Swedish iron and steelmaker to receive this great honour. This year the Council of The Iron and Steel Institute showed its appreciation of Professor Kalling's work by awarding him the Bessemer Gold Medal.

Professor Bo Kalling

Bessemer Gold Medallist, 1959

PROCEEDINGS OF

THE INSTITUTE

Reports of Council · Meetings · Notices

Report of Council for 1958

THE COUNCIL submit this, their Annual Report and Statement of Accounts for the year 1958, to Members for their approval at the 90th Annual General Meeting of The Iron and Steel Institute.

The 89th Annual General Meeting and the Autumn General Meeting 1958 were held in London in May and December, respectively. The Engineers Group held three meetings, two in London and one in Chester. Joint meetings were held with Affiliated Local Societies in steelmaking districts.

ROLL OF THE INSTITUTE

The total membership at 31st December, 1958 was 5 098, compared with 4 990 on the last day of 1957. This is a larger number than on any previous occasion.

During the year 297 Ordinary and 76 Associate Members were elected or reinstated. The deaths of 67 Members were reported; 130 resigned, one was transferred to the Service Suspense List, 61 were struck off the Roll of Members, and 6 elections lapsed for non-payment of subscriptions.

An analysis of the Membership at 31st December, 1958, is given in Table I, and the membership trend since the formation of the Institute is shown in Fig. 1.

OBITUARY

The Council regret to announce the deaths of the following 67 Members, which were reported during 1958:

AIREDALE OF GLEDHOW, The Rt Hon. Lord (London)	20th March, 1958
BARCLAY, D. K. (Redcar)	28th January, 1958
BENEDICKS, C. A. F. (Stockholm, Sweden)	16th July, 1958
BENT, Q. (Bethlehem, Pa., USA)	5th May, 1957
BOOL, E. D. (Sheffield)	1st December, 1958
BUCHANAN, J. G. (London)	22nd April, 1958
CHESTON, P. H. (London)	9th October, 1958
CRAWFORD, J. L. (Glasgow)	Not known
DEAN, A. L. (Rowley Regis)	October, 1957
DELPORT, V. (London)	3rd June, 1958
DESCH, C. H. (London)	19th June, 1958
DIXON, E. O. (Milwaukee, Wis., USA)	4th November, 1956
DONNELLY, V. J. (Boksburg North, Transvaal, S. Africa)	November, 1957
DUNBAR, J. (Musselburgh)	16th December, 1958
EISENMAN, W. H. (Cleveland, Ohio, USA)	30th May, 1958
ELWELL, J. (Wolverhampton)	April, 1958
FOULD, E. (Paris, France)	October, 1957
FRANKLIN, W. W. (Bamford, nr. Sheffield)	18th December, 1957
GEARY, W. (Scunthorpe)	12th January, 1958
GEORGE, C. W. (Farnborough)	25th April, 1958
GILLIGAN, F. P. (Hartford, Conn., USA)	Not known
GREAVES, R. H. (London)	20th January, 1958
GRESTY, C. (Wallsend-on-Tyne)	9th September, 1957
GRIFFITHS, L. (Port Talbot)	4th November, 1958
HAND, T. W. (Hathersage)	29th August, 1958
HENSHAW, P. B. (Sheffield)	24th May, 1958
HERASYMENKO, P. (Bronx, NY, USA)	6th April, 1958
HOUDREMONT, E. (Essen-Bredeney, Germany)	10th June, 1958
HUSBAND, G. (Stockton-on-Tees)	24th September, 1958
JOHNSON, A. A. (Stockholm, Sweden)	3rd August, 1958
KEATING, F. H. (Stockton-on-Tees)	16th August, 1958
KENT, A. E. (Vereeniging, S. Africa)	6th September, 1958
KING, A. E. (Cardiff)	13th November, 1957
KUGEL, E. (Köln-Deutz, Germany)	29th November, 1958
LANG, C. B. (Montreal, Canada)	February, 1958
LOVELEE, J. A. (Kettering)	Not known
MCCOY, F. A. (Kansas City, Kansas, USA)	25th August, 1958
MACKENZIE, J. T. (Birmingham, Ala., USA)	17th November, 1958
MCLEOD, A. (London)	3rd January, 1958
MACNAIR, P. M. (Swansea)	24th November, 1958
MARSHALL, J. N. (Granite City, Ill., USA)	15th April, 1958
MORGAN, P. V. (London)	Not known
O'SULLIVAN, P. (Ilford)	26th April, 1958
POOLE, A. (Sheffield)	16th July, 1958
PREECE, A. (Newcastle-on-Tyne)	3rd November, 1958
RATY, J. (Paris, France)	20th June, 1958
REECE, T. H. (Walton-on-Thames	7th March, 1958
REYNOLDS, E. H. (Scunthorpe)	24th August, 1958
RICE-OXLEY, F. B. (London)	18th August, 1958
ROLFE, R. T. (Bedford)	9th December, 1958
ROSE, F. (Keston)	2nd May, 1958
RUIZ, E. O. (Guipuzcoa, Spain)	3rd December, 1956
SCHARLE, A. (Belo Horizonte, Brazil)	30th June, 1956
SCHIELDROP, B. (Stotfold)	2nd July, 1958
SIMPSON, F. F. L. (Bideford)	Not known
SIMPSON, H. T. (Bilbao, Spain)	Not known
SLOTTMAN, G. V. (New York, NY, USA)	21st April, 1958
STAGG, F. R. (Sheffield)	14th November, 1958
TAYLOR, A. (Middlesbrough)	September, 1958

TABLE I

Membership of The Iron and Steel Institute at 31st December, 1958 and comparison with 1957

	Membership at 31st December, 1958													1957		
	Ordinary membership		Joint membership with								Total membership		Grand totals	Total membership		Grand totals
			Institute of Metals		Institution of Metallurgists		Both Institute and Institution		Totals							
	Home	Overseas	Home	Overseas	Home	Overseas	Home	Overseas	Home	Overseas	Home	Overseas		Home	Overseas	
Patron	1	...	...	...	...	...	...	...	...	...	1	...	1	1	...	1
Members																
Hon. Vice-Presidents	6	12	2	1	...	...	1	...	3	1	9	13	22	7	10	17
Hon. Members	2	7	...	1	...	...	1	1	1	2	3	9	12	3	9	12
Non-paying Members	4	1	...	...	...	...	...	...	...	...	4	1	5	5	1	6
Life Members	57	35	4	6	6	...	7	1	17	7	74	42	116	73	45	118
Ordinary Members	1 785	923	451	369	569	59	447	63	1 467	491	3 252	1 414	4 666	3 219	1 359	4 578
Total (Members)	1 855	978	457	377	575	59	456	65	1 488	501	3 343	1 479	4 822	3 308	1 424	4 732
Associate Members	57	12	169	14	14	1	9	...	192	15	249	27	276	229	29	258
Total (both classes)	1 912	990	626	391	589	60	465	65	1 680	516	3 592	1 506	5 098	3 537	1 453	4 990

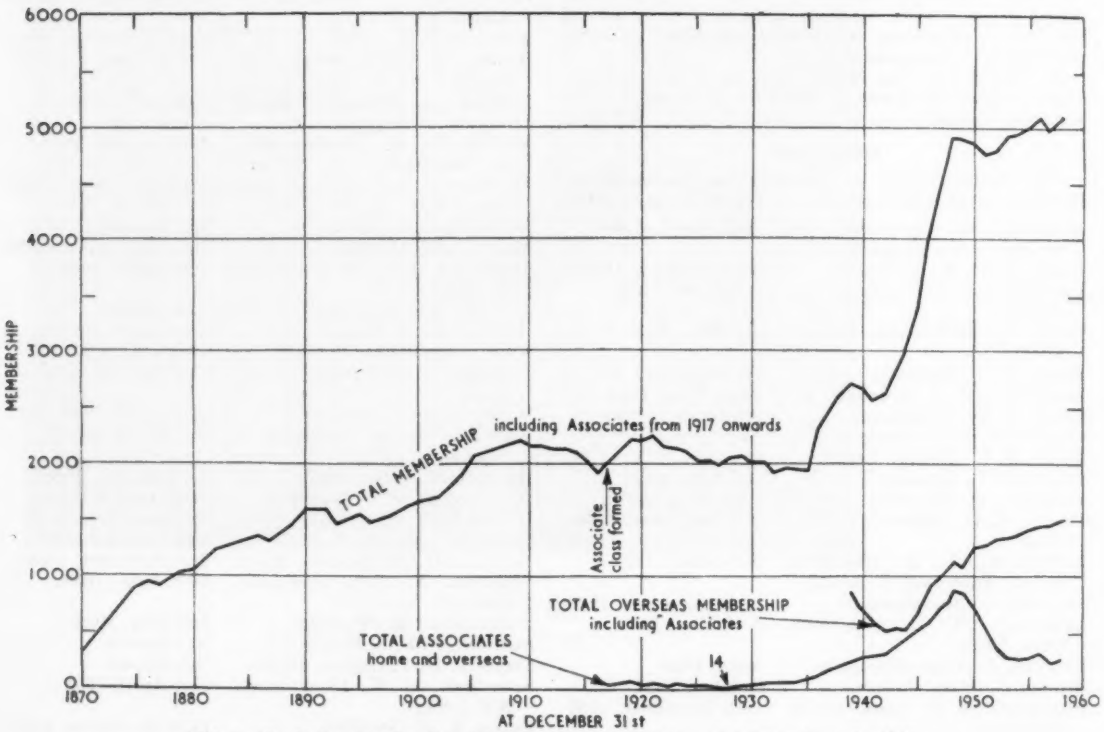

Fig. 1—Variation in Membership since the foundation of the Institute in 1869

THOMSON, S. (Motherwell)	7th September, 1958
TORNBLAD, J. (Belfast)	14th July, 1958
VER, T. (Cincinnati, Ohio, USA)	30th November, 1957
WAUGH, P. W. (Sevenoaks)	20th November, 1957
WESSON, A. J. (Wednesbury)	June, 1957
WHITHAM, J. H. (Sheffield)	May, 1957
WOLF, W. A. L. (Kettering)	7th March, 1958
ZIMMERMAN, F. M. (Svermova, Czechoslovakia)	6th November, 1958

The Rt Hon. Lord Airedale of Gledhow, D.S.O., M.C., had been a Member of the Institute since 1906; he became a Member of Council in 1924, a Vice-President in 1930, and an Honorary Vice-President in 1957.

Dr C. H. Desch, D.SC, LL.D., F.R.S., was a Past-President (1946–1948) and an Honorary Member of the Institute since 1950; he received the Bessemer Gold Medal in 1938. He became a Member in 1913, a Member of Council in 1924, and a Vice-President in 1930.

Mr W. H. Eisenman had been elected an Honorary Member in 1955; he had been secretary of the American Society for Metals since 1918.

Professor C. A. F. Benedicks, PH.D., DR ING.E.H., joined the Institute in 1905 and was elected an Honorary Vice-President in 1922. He received an Andrew Carnegie Gold Medal in 1908 and was awarded the Bessemer Gold Medal in 1927.

Mr S. Thomson, who joined the Institute in 1937, was elected a Member of Council in 1951 and a Vice-President early in 1958.

Mons. J. Raty had been elected an Honorary Member in 1956; he was President of the Chambre Syndicale de la Sidérurgie Française.

Mr E. D. Bool, at the time of his death, was President of the Sheffield Society of Engineers and Metallurgists, and had served the Institute as an Honorary Member of Council during his presidency. He became a Member in 1935.

The following had been Members for 50 years or more: Mr Quincy Bent (1905) and Mr A. A. Johnson (1906); and the following for 40 years or more: Mr P. B. Henshaw (1909), Mr C. W. George (1917), Mr T. W. Hand (1917), and Mr F. P. Gilligan (1918). The dates of the deaths of the following have not been reported but it is believed that they were Members for more than 50 years: Mr F. F. L. Simpson (elected in 1880), Mr H. T. Simpson (1892), and Mr P. V. Morgan (1897).

HONORARY MEMBERS OF THE INSTITUTE

His Majesty King Baudouin, King of the Belgians, and H.R.H. Charlotte, Grand Duchess of Luxembourg, honoured the Institute by accepting Honorary Membership on the occasion of the Special Meeting held in Belgium and Luxembourg in June, 1958.

The election of Dr H. Moore, C.B.E., a Member since 1901, as an Honorary Member of the Institute was announced at the Autumn General Meeting.

CHANGES ON THE COUNCIL

President-Elect

It was announced at the Autumn General Meeting, 1958, that the Council had unanimously decided to nominate Mr William Barr, O.B.E. (Honorary Treasurer), for election as President at the Annual General Meeting, 1959, to hold office for one year.

Honorary Treasurer

Sir Julian Pode accepted an invitation to succeed Mr Barr as Honorary Treasurer as from the Annual General Meeting, 1959.

Honorary Vice-Presidents

Monsieur L. Bouvier (President, Groupement des Industries Sidérurgiques Luxembourgeoises), Monsieur F. Perot (President, Centre National de Recherches Métallurgiques), and Monsieur P. van der Rest (President, Groupement des Hauts-Fourneaux et Aciéries Belges) were elected Honorary Vice-Presidents of the Institute.

Other changes

Mr E. T. Judge, Mr D. A. Oliver, C.B.E., Mr F. H. Saniter, and Dr C. Sykes, C.B.E., F.R.S., were elected Vice-Presidents, and Dr J. H. Chesters, Mr F. B. George, Mr W. F. Gilbertson, Dr L. B. Pfeil, O.B.E., F.R.S., and Mr R. F. Summers were elected Members of Council.

Honorary Members of Council

Marshal of the Royal Air Force The Lord Tedder, G.C.B., D.C.L., LL.D., President of The Institute of Metals, agreed to serve as an Honorary Member of Council during his term of office, following Dr L. B. Pfeil, O.B.E., F.R.S. Dr H. Harris continued to serve as an Honorary Member of Council as President of the West of Scotland Iron and Steel Institute.

The following agreed to serve as Honorary Members of Council during their Presidencies of the Affiliated Local Societies named: Mr T. H. Stayman (Cleveland Institution of Engineers, following Mr T. W. Thursfield); Mr N. S. Angus (East Midlands Metallurgical Society, continuing Presidency); Mr P. T. Edwards (Ebbw Vale Metallurgical Society, following Mr J. T. Mills); Mr K. Hill (Leeds Metallurgical Society, following Mr P. A. Green); Mr A. H. Norris (Lincolnshire Iron and Steel Institute, continuing Presidency); Dr C. Bodsworth (Liverpool Metallurgical Society, following Mr J. S. W. Graham); Mr Johnson Y. Davies (Manchester Metallurgical Society, following Dr K. M. Entwistle); Mr H. H. Stanley (Newport and District Metallurgical Society, following Mr C. I. F. Mackay); Mr H. Brooke Freeman (North Wales Metallurgical Society, continuing Presidency); Mr R. C. Baker (Sheffield Metallurgical Association, continuing Presidency); Mr H. Bull (Sheffield Society of Engineers and Metallurgists, following Mr E. D. Bool, died in office); Mr W. H. B. Wesson, T.D. (Staffordshire Iron and Steel Institute, following Mr G. Parkin); Professor R. Higgins, O.B.E., PH.D. (Swansea and District Metallurgical Society, following Mr J. S. Caswell, M.SC.).

Mr E. J. Bradbury and Mr W. E. Bardgett continued to represent The Institution of Metallurgists on the Council.

The Council decided to elect not more than six Additional Honorary Members of Council, who would serve normally for a period of three years, in order to broaden the representation of Members on the Council.

Mr R. W. Evans (The Steel Company of Wales Ltd) and Dr L. F. C. Northcott (Armament Research and Development Establishment) accepted invitations to serve as Additional Honorary Members of Council from the Annual General Meeting, 1958.

AWARDS AND PRIZES

The *Bessemer Gold Medal* for 1958 was awarded to Mr W. F. Cartwright, Vice-President (Steel Company of Wales Ltd) in recognition of his distinguished contributions in the field of the design, development, and organization of modern iron and steelworks, and in furtherance of steelworks engineering in all its branches.

The *Sir Robert Hadfield Medal* for 1958 was awarded to Mr W. C. F. Hessenberg, Honorary Member of Council (British Iron and Steel Research Association), in recognition of his distinguished career in the British Iron

and Steel Research Association, and of his contribution to rolling-mill research.

The *Andrew Carnegie Silver Medal* for 1957 was awarded to Mr S. W. K. Shaw (Sheffield University) for his report on "The formation of carbides in low-carbon chromium–vanadium steels at 700° C" (*Journal*, 1957, vol. 185, Jan., pp. 10–22). His co-author, Professor A. G. Quarrell, was not eligible for an award.

Two *Williams Prizes* for 1957 of £50 each were awarded to Mr C. Holden and Mr A. D. Robertson (both of The United Steel Companies Ltd) for their paper on the "Protection of refractories by moving air curtains" (*Journal*, 1957, vol. 185, Feb., pp. 177–200). Their co-author, Dr J. H. Chesters, was not eligible for an award.

Two *Ablett Prizes* for 1957 of £50 each were awarded to Mr C. E. H. Morris and Mr R. N. Dale (both of the Steel Company of Wales Ltd) for their paper on "Planning the conversion of a high lift slabbing mill to a universal mill" (*Journal*, 1957, vol. 185, Apr., pp. 532–552).

ANDREW CARNEGIE RESEARCH GRANTS

During 1958 the following grants were made from the Andrew Carnegie Research Fund:

R. E. M. Ball (Imperial College of Science and Technology): £400 (second grant) for a research on the effect of the length of test-piece and stored energy on the brittle fracture of steel.

W. D. Brentnall (Manchester University): £400 for a research on the structure of metallic meteorites.

I. M. Davidson (Liverpool University): £380 (second grant) for an investigation of oxygen potentials in simple slags.

K. Farrell (Sheffield University): £400 for a research on the embrittling effect of hydrogen on ultra-high-tensile steels.

A. Gilbert (Liverpool University): £50 for a research on the M_s temperature in binary alloys with restricted gamma fields.

T. Gladman (Sheffield University): £400 (second grant) for an investigation on the effect of hydrogen on transformations in alloy steels.

J. G. Humphreys (Liverpool University): £380 (second grant) for a research on carbide constituents in iron–carbon–silicon alloys.

E. F. Ibrahim (Sheffield University): £250 for an investigation of martensite transformation curves.

C. N. Reid (Liverpool University): £80 for an experimental study of time-dependent strain in iron at sub-zero temperatures.

J. S. White (Liverpool University): £50 (second grant) for a research on the effect of partial decomposition of austenite to lower bainite upon the completion of the decomposition to upper bainite.

MOND NICKEL FELLOWSHIPS

Mr F. H. Saniter continued to represent The Iron and Steel Institute on the Mond Nickel Fellowships Committee.

The Committee made the following Awards for 1958:

G. H. Longworth (Lancashire Steel Manufacturing Co. Ltd) to study the manufacture of plain carbon and alloy steels for rod and wire products in the UK, on the Continent, and in the USA.

J. C. Morrison (Carron Company Ltd) to study melting, moulding, and heat-treatment of alloy cast irons, quality control of metal, and sand plants in modern foundries, and new developments in related metallurgical processes.

T. Tait (Colvilles, Ltd) to study the technical and economic factors involved in the use of oxygen in steel industries in the UK, on the Continent, and in the USA and Canada.

MEETINGS

Annual General Meeting, 1958

The 89th Annual General Meeting was held at the Offices of the Institute on the afternoon of Wednesday and all day Thursday, 7th and 8th May. On the Wednesday afternoon, after the transaction of formal business, including the presentation and approval of the Report of Council and Statement of Accounts and the election of Members, Mr A. H. Ingen-Housz, the Retiring President, inducted Mr C. R. Wheeler, C.B.E., into the Chair. The new President then delivered his Presidential Address on "Raw material supplies and the future development of the iron and steel industry" (*Journal*, 1958, vol. 189, June, pp. 101–109).

Papers on various subjects were discussed on the Thursday.

The proceedings of the meeting are recorded on pp. 197–200 of the *Journal* for July, 1958, and the reports of the discussions on pp. 284–305 of the issue for November, 1958.

The Dinner for Members held at Grosvenor House, on Wednesday, 7th May, was attended by about 1 500 members and guests. The speakers included the Rt. Hon. Reginald Maudling, P.C., M.P., Her Majesty's Paymaster-General, and Mr P. van der Rest (Honorary Vice-President).

Autumn General Meeting, 1958

The Autumn General Meeting was held in London on Wednesday, 10th December. An all-day session on continuous casting, with the President in the Chair, was held simultaneously with half-day discussions on creep and on the effect of hydrogen in weld metal, under the chairmanship of Mr W. Barr (Hon. Treasurer). The session on hydrogen in weld metal was a Joint Meeting with the Institute of Welding.

The proceedings of the Meeting are recorded on pp. 217–218 of the March, 1959, issue of the *Journal* and the discussions will be published in the *Journal* later this year.

Eleventh Hatfield Memorial Lecture

Dr N. P. Allen, F.R.S. (Superintendent, Metallurgy Division, National Physical Laboratory), gave the Eleventh Hatfield Memorial Lecture in London on the evening of Tuesday, 9th December. His subject was "The mechanical properties of the ferrite crystal." The lecture is printed on pp. 1–18 of the January, 1959, issue of the *Journal*.

Special Meeting in Belgium and Luxembourg

Following an invitation from the Presidents of the Centre National de Recherches Métallurgiques, the Groupement des Industries Sidérurgiques Luxembourgeoises, and the Groupement des Hauts-Fourneaux et Aciéries Belges, the Institute held a Special Meeting in Belgium and Luxembourg from 17th to 28th June, 1958. The first section was held in Liège and was a joint meeting with the Journées Internationales de Sidérurgie, organized by the Centre National de Recherches Metallurgiques, Section de Liège. During their stay in Brussels, Members and Ladies visited the International Exhibition, by invitation of the Groupement des Hauts-Fourneaux et Aciéries Belges. His Majesty King Baudouin, King of the Belgians, and H.R.H. Charlotte, Grand Duchess of Luxembourg, graciously consented to be Patrons of the Meetings, which, also,

were under the patronage of the Belgian and Luxembourg Governments.

Members and their Ladies spent four days in and near Liège, four more in the Grand Duchy of Luxembourg, and three days in and around Brussels from where visits were paid to Charleroi, by invitation of the Centre National de Recherches Métallurgiques, Section de Hainaut, and of the iron and steelworks of the district. Ten Sessions were arranged for the discussion of various aspects of iron and steelmaking, the chief subjects being recent developments in steelmaking (Liège), recent developments in ironmaking (Luxembourg), and the continuous casting of steel (Charleroi). A large number of works were visited. An excellent programme was provided for the Ladies and pleasant social functions arranged for Members and Ladies.

Details of the programme of the Meeting and of the papers, with an indication of the procedure for publishing them, appeared on pp. 12–14 of the May, 1958, issue of the *Journal*, whilst summaries of all the papers were printed on pp. 109–112 and 168 of the June *Journal*. The papers presented at sessions in Liège and in Charleroi (during the Brussels section of the Meeting) were printed in their languages of origin in the *Revue Universelle des Mines*, 1958, vol. 14, No. 12, and those presented in Luxembourg in the *Revue Technique Luxembourgeoise*, 1958, vol. 50, No. 2, Apr./June, and 1959, vol. 51, No. 1, Jan./Mar. These papers, together with the contributions to the discussion on them, and a short note on the proceedings, have been collected together in a single volume under the title "Journées Internationales de Sidérurgie, Liège, Luxembourg, Charleroi et Bruxelles, 18–28 Juin, 1958; Comptes Rendus."

IRON AND STEEL ENGINEERS GROUP

Mr F. B. George agreed to become Chairman of the Iron and Steel Engineers Group on the conclusion of Mr W. M. Larke's period of office. The Engineering Committee, which organizes the activities of the Group, was composed of the following Members as from May, 1958:

Chairman

Mr F. B. George

Members

Mr W. S. Atkins	Mr R. Cameron
Mr D. L. Campbell	Mr H. Darnell
Mr D. R. Eastwood	Mr R. M. L. Elkan
Mr R. A. Lake	Mr W. M. Larke
Mr S. A. Lewitt	Mr H. M. Morgan
Mr J. Morgan	Mr R. Stewartson
Mr G. Warrior	Mr N. T. Williams

Ex-Officio

Mr C. R. Wheeler, C.B.E.
Mr W. Barr, O.B.E. Dr H. R. Mills

The Group held a two-day meeting in London in April to discuss modern applications of the Ward-Leonard principle in steelworks, electrical maintenance, and remote position control in rolling mills and in forging.

In October a three-day meeting took place in Chester; the papers were concerned with crane safety, crane design, and some applications of ergonomics in iron and steelworks and a whole-day visit was paid to the Irlam Works of the Lancashire Steel Manufacturing Co. Ltd.

In December a one-day meeting in London (held in conjunction with the Institute's Autumn General Meeting) was concerned with vacuum processes in the iron and steel industry.

The papers discussed at the above meetings are printed in the *Journal*.

POWDER METALLURGY JOINT GROUP

The Powder Metallurgy Joint Group of The Iron and Steel Institute and The Institute of Metals held two meetings. The first, on 19th March, was an informal discussion on developments in the practice of compacting and sintering, and the second, on 16th–17th December, was a symposium on the powder metallurgy of ceramic–metal materials.

The papers and proceedings at the above meetings are printed in 'Powder Metallurgy—Official Publication of the Powder Metallurgy Joint Group of The Iron and Steel Institute and The Institute of Metals,' of which the first (double) issue, No. 1–2, 1958, was published during the year by The Institute of Metals on behalf of both Institutes.

BRITISH NUCLEAR ENERGY CONFERENCE

The British Nuclear Energy Conference, of which the Institute is a Member, organized meetings to discuss papers on various aspects of nuclear energy and related subjects, and co-ordinated into a joint programme meetings held by the constituent Institutions.

PUBLICATIONS

Journal

As usual, the *Journal* was published in twelve monthly parts, comprising volumes 188, 189, and 190. Indexes and binding cases are being prepared.

Special Reports

Three Special Reports were published during the year:

No. 61 "Air and water pollution in the iron and steel industry" (1958)

No. 62 "The determination of nitrogen in steel" (1958)

No. 63 "Surface defects in ingots and their products" (2nd edition) (1958).

Bibliographies

A continuation of nos. 13 and 13a in the bibliographical series, "Bibliography on wire; manufacture, treatment and properties," was produced as no. 13b: this covered the period 1950–1957.

List of Members

The List of Members, 1958, giving names of Members arranged both alphabetically and topographically, was issued during the year.

Other Publications

The Institute continued to assist in the production of the *British Foundryman* and the *Transactions of the Society of Instrument Technology*, but, under a revised agreement, ceased to assist in the editing of the *British Welding Journal*.

TRANSLATION SERVICE

The title of the co-operative translation service, operated by a number of companies in the steel industry and organized by the Institute, was changed to the 'British Iron and Steel Industry Translation Service.'

With the help of the co-operating companies which contributed over 80% of the translations, 398 translations were issued in 1958. Of these 196 were from German, 106 from Russian, 63 from French, and the remainder from six other languages.

Fortnightly lists of translations are sent to over 200 addresses. In the first year's list of translations, entitled *Iron and Steel Translations* 1957/58, titles are in classified order, with author and subject indexes, and the list is supplemented by six-weekly classified *Iron and Steel Translations Lists*. Complete lists of new translations are also published in the Institute's *Journal*, in

the BISRA *Report Lists*, and as a supplement in alternate weeks to the British Iron and Steel Federation's *Review of British and Foreign Press*.

Co-operation has been developed with the steel companies and with other translating organizations in the UK and the USA; advance information of proposed translations is exchanged, to prevent articles from being translated twice over. Translations prepared by other organizations are being recorded, including those from Eastern languages into French and German.

Enquiries for new translations are welcomed; if suitable, they are included in the Service. During 1958 76 such articles were included and 26 translations were prepared specially.

JOINT LIBRARY AND INFORMATION DEPARTMENT

During the year, 14 038 publications were borrowed from the Joint Library of the Institute and the Institute of Metals (13 847 in 1957). As in previous years nearly one thousand additional publications were issued to members of the staffs of the two Institutes. During 1958, 449 textbooks were acquired, an increase of nearly 30% over 1957 (351). The Council wish to thank those who generously presented copies of their books and papers to the Joint Library.

A considerable extension has taken place in the holding and utilization by the Joint Library and Information Department of literature published in the UK and abroad. A large number of published papers, books, and periodicals from the USA, the USSR, and other countries, not previously obtained, has been received.

Photographic copies of documents can, under certain conditions, be supplied to Members. During 1958, 108 photocopies and 40 microfilms were prepared, a decline on the previous year (187 and 51).

The services of the Information Department, like those of the Joint Library, were well used by Members, Government Departments, Universities, Research Associations, and commercial organizations, and included the giving of information on a wide variety of problems as well as the provision of bibliographies and lists of references (*see also* ' Bibliographies ' under ' Publications ' above).

Additional space is required for storage at basement level and for the staff of the Library and Information Department at ground-floor level of the Institute's offices at 4 Grosvenor Gardens. Accordingly, plans were approved for demolishing existing structures at the back of the building and extending the main building at basement and ground-floor levels, work to begin early in 1959 and the cost to be charged to the House Fund.

As a temporary measure, the main reading room was divided, part being made available to Members and part being used by the staff.

Co-operation with the British Iron and Steel Research Association

During the course of the year there has been a considerable development in the co-operation between the Library and Information Service of the Institute and the British Iron and Steel Research Association. Regular meetings and visits have been arranged between the respective staffs. Indexes and holdings of books and periodicals have been compared and revised. Progress has been made in methods of making available to their respective Members scientific and technical information derived from both organizations.

RELATIONS WITH OTHER SOCIETIES AND ORGANIZATIONS IN THE UK AND OVERSEAS

A continuation of friendly co-operation has been maintained with many scientific and technical societies at home and overseas, and especially with The Institute of Metals, The Institution of Metallurgists, and the West of Scotland Iron and Steel Institute. Friendly relationships with the Iron and Steel Board, the British Iron and Steel Federation, and the British Iron and Steel Research Association have also been maintained.

The Institute of Metals

The Institute of Metals celebrated its Golden Jubilee at its Annual General Meeting during the week beginning 28th April, 1958. The Council of The Iron and Steel Institute, on behalf of all Members, sent warm congratulations on its past achievements and all good wishes for its continuing prosperity and success in the future.

Affiliated Local Societies in the UK

The following are the 13 Local Societies affiliated with the Institute:

Cleveland Institution of Engineers
East Midlands Metallurgical Society
Ebbw Vale Metallurgical Society
Leeds Metallurgical Society
Lincolnshire Iron and Steel Institute
Liverpool Metallurgical Society
Manchester Metallurgical Society
Newport and District Metallurgical Society
North Wales Metallurgical Society
Sheffield Metallurgical Association
Sheffield Society of Engineers and Metallurgists
Staffordshire Iron and Steel Institute
Swansea and District Metallurgical Society.

Arrangements for affiliation remained unchanged and continued to operate to the mutual advantage of the Affiliated Societies and the Institute.

The Newport and District Metallurgical Society celebrated the 25th Anniversary of the foundation of the Society at a Silver Jubilee held at Newport, Mon., on 25th October, at which the President represented the Institute.

Joint meetings

The Institute took part in joint meetings organized by the Ebbw Vale Metallurgical Society on 20th March, and with the Sheffield Metallurgical Association and the Sheffield Society of Engineers and Metallurgists on 4th November. Besides these special occasions, Institute members were entitled to attend ordinary meetings of the Affiliated Societies.

Metallurgical societies overseas

The number of ' kindred ' societies overseas is now 20 as follows:

American Institute of Mining, Metallurgical, and Petroleum Engineers
American Iron and Steel Institute
American Society for Metals
Associação Brasileira de Metais (Brazil)
Association des Ingénieurs Sortis de l'Ecole de Liège (Belgium)
Associazione Italiana di Metallurgia (Italy)
Association Luxembourgeoise des Ingénieurs et Industriels (Luxembourg)
Australian Institute of Metals
Canadian Institute of Mining and Metallurgy
Indian Institute of Metals
Instituto del Hierro y del Acero (Spain)
Jernkontoret (Sweden)
Koninklijk Institut van Ingenieurs (Holland)
Norsk Metallurgisk Selskap (Norway)
Sociedad Argentine de Metales (Argentine)
Société Française de Métallurgie (France)
Société Royale Belge des Ingénieurs et des Industriels (Belgium)
Verein Deutscher Eisenhüttenleute (Germany)

Verein Eisenhütte Oesterreich (Austria)
Verein Schweizerischer Maschinen-Industrieller (Switzerland)

Members of the Institute who are members of, or are on the staff of member firms of any of the above societies if resident in the countries concerned, pay reduced membership subscriptions to the Institute. Reciprocal reductions in subscription are granted by a number of the 'kindred' societies to Members of the Institute.

REPRESENTATION AT MEETINGS AND MEMBERSHIP OF MISSIONS OVERSEAS

The President, Mr C. R. Wheeler, C.B.E., represented the Institute at the Annual Meeting and Dinner of the American Iron and Steel Institute in New York on 21st May.

Mr A. H. Ingen-Housz (Past President) represented the Institute at the Golden Jubilee celebrations of The Institute of Metals in April, and at the Annual General Meeting of the Verein Deutscher Eisenhüttenleute on the 6th November.

The new pilot plant of IRSID at Maizières-les-Metz was opened on the 22nd April, 1958; the Institute was represented by the Secretary.

The Secretary attended the Annual General Meeting of Jernkontoret, which was held on 31st May in Stockholm, and also the centenary celebrations held at Sandviken, Sweden, on the 18th July, to commemorate the success of the experiments carried out at Edsken for developing the Bessemer process. He then presented to the Sandvik Steel Co. Ltd, on behalf of the Institute, a section cut from a rail rolled from material from an early Bessemer blow at Dowlais.

The Secretary visited the USA during October and November, by invitation of the American Society for Metals, and delivered the lecture at the Annual Awards Luncheon of the American Society for Metals in Cleveland, Ohio, on 28th October.

The Assistant Secretary was a member of a mission which visited Moscow during October under the leadership of Sir Charles Goodeve, F.R.S. (Vice-President and Director of BISRA) in order to visit research establishments associated with the Russian steel industry and to improve the arrangements for the exchange of technical information.

The Information Officer (Mr J. P. Saville) attended Committee C 621 of the International Federation for Documentation to discuss the classification by the Universal Decimal Classification of Engineering Workshop Practice, at The Hague on 8th to 11th September.

EDUCATION

Joint Committee for National Certificates in Metallurgy

The Institute was represented on the Joint Committee for National Certificates in Metallurgy by Dr J. W. Jenkin and the Secretary.

Sheffield University: Institute Prize, 1958

The Iron and Steel Institute Prize for 1958 at Sheffield University was awarded to Mr Peter Beardmore.

WORSHIPFUL COMPANY OF BLACKSMITHS

Mr D. L. Campbell, M.C. (a Member since 1937) was nominated for admission to the Blacksmiths Company under the arrangement by which the Council is privileged to put forward annually two applications for nomination for admission to the Company at reduced fees.

HONOURS CONFERRED UPON MEMBERS

The Council offer their congratulations to all Members who have received Honours or appointments during the year. The names have been recorded in the News Section of the *Journal*.

RECOVERY OF INCOME TAX

The Commissioners of Inland Revenue have approved The Iron and Steel Institute for the purposes of Section 16 of the Finance Act, 1958. As a result, starting with the year ending 5th April, 1959, a Member or Associate Member of The Iron and Steel Institute who is assessable to income tax under schedule E in respect of the emoluments of an office or employment is entitled to a deduction from those emoluments of the whole of the annual subscription which is due and payable by him to the Institute in the income tax year, provided that the subscription is defrayed out of the emoluments of the office or employment and that such offices or employment is directly relevant to the activities of the Institute.

Any Member or Associate Member of The Iron and Steel Institute who is entitled to the relief should apply to his Income Tax Office as soon as possible for form P.358 on which to make a claim for adjustment of his 'pay as you earn' coding.

This concession applies only to those Members and Associate Members of the Institute, who are subject to UK Income Tax Regulations, but particulars are being circulated to all Members and Associate Members so that they may all be aware of the concession, should they at any time become subject to UK Income Tax Regulations.

FINANCE

The Accounts for 1958 are appended. (Figures for the previous year are printed in brackets for comparison.)

GENERAL FUND

Balance Sheet and Income and Expenditure Account

The Balance Sheet at 31st December, 1958, and the Income and Expenditure Account for the year ending on that date, are submitted in the usual form.

Ordinary Expenditure at £105,582 (£95,021) exceeded ordinary income £104,578 (£97,964) by £1,004. After taking in certain special items, the sum of £158 (£1,801) excess of income, was transferred to the Accumulated Fund.

Transfers of £1,750 were made from the Accumulated Fund to Reserves and the balance £33,815 (£35,268) was carried to the Balance Sheet.

A further £1,757 has been written off the value of the lease of No. 4 Grosvenor Gardens, London S.W.1. The total amount written off this lease, which runs for 60 years from September, 1955, is £9,038 and its value in the Balance Sheet is now £35,519. The total value of the House Fund is £57,450 (£57,160).

TRUST FUNDS

The Accounts of the Andrew Carnegie Research, Williams Prize, Bessemer Medal, and Sir Robert Hadfield Medal Funds are presented as usual. Full use has again been made of the available income.

INVESTMENTS

Most of the stocks in which the funds of the Institute and the Trust Funds are invested have fixed investment values and dates. The investments are valued in the Balance Sheets at what they cost when purchased. In the case of the General and House Funds, the cost was £48,814 and their market value at 31st December, 1958, was £43,988 (£40,614). In the case of the four Trust Funds the cost was £38,607* (£38,683) and their market value at 31st December, 1958, was £36,436 (£32,486).

*This figure includes £474 15*s* 0*d* British Transport 3% Guaranteed Stock 1978–1988 at the figure of £400, at which it is included in the Balance Sheet of the Bessemer Medal Fund.

THE IRON AND STEEL INSTITUTE

BALANCE SHEET, 31ST DECEMBER, 1958

General Account

1957 £	£	LIABILITIES	£	£	1957 £	£	ASSETS	£	£
		Accumulated Fund					*Furniture and Fittings*		Not Valued
35,268		Balance per Account annexed		33,815	1,500		*Motor Cars at Written Down Value:*		2,382
		Current Liabilities and Provisions:			29,953		*Investments at Cost per Schedule*		29,953
17,041		Sundry Creditors (part estimated)	14,254				(Market value at 31st December, 1958, £24,488)		
852		Due to House Fund	2,751				*Current Assets:*		
44		Due to Sir Robert Hadfield Medal Fund	49			3,523	Stock of Paper as valued by the Managing Editor	1,514	
42		Due to Bessemer Medal Fund	50			22,942	Sundry Debtors	20,553	
42		Ablett Prize Fund Account	43			1,433	Deposits and Payments in Advance	1,519	
252		Subscriptions received in advance	289			466	Balances at Banks and Cash in hand	166	
6,237		Payments received in advance for Publications	3,873		28,364				23,752
		Sundry Provisions as at 31st December, 1958:					*Activities in Connection with Publications:*		
		Reserve for Comprehensive Index	1,400		5,372		Expenditure incurred in advance on Publications		2,926
		Transfer from Accumulated Fund	250						
			1,650		61		*Special Publications Suspense Account*		—
1,400		*Less* Expenditure during year	1,400	250					
		Reserve for Supplementing Staff Pensions	3,000						
3,000		Transfer from Accumulated Fund	500						
				3,500					
				3,750					
1,072		Bank Overdraft		—					
29,982				25,059					
		Special Publications—Suspense Account		139					
£65,250				£59,013	£65,250				£59,013

Special Funds

1957 £	£		£	£	1957 £		£	£
		House Fund:				*House Fund:*		
		Amount received from Companies	56,700			Lease at Cost less amount written off, per Account annexed	35,519	
57,160		Amount receivable in 1958	750			Sundry Debtor	319	
				57,450		Investments at Cost, per Schedule	18,861	
						(Market Value at 31st December, 1958, £17,837)		
					57,160	Due from General Fund	2,751	
								57,450
£122,410				£116,463	£122,410			£116,463

We have examined the above Balance Sheet of the Institute and found it to be correct.

FINSBURY CIRCUS HOUSE,
BLOMFIELD STREET,
LONDON, E.C.2
19th March, 1959

(*Signed*) W. B. KEEN & Co.
Chartered Accountants

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31ST DECEMBER, 1958

EXPENDITURE

1957 £	£		£	£
		Staff Expenses:		
36,348		Salaries and National Insurance	42,033	
3,161		Staff Superannuation Fund and Pension	3,390	
1,562		Cost of Staff Luncheon Vouchers	2,015	
41,071	47,438			
		Office Administrative Expenses:		
2,331		Printing and Stationery	2,552	
848		Postage and Receipt Stamps	1,233	
2,696		Travelling and Entertainment	3,255	
431		Meetings	2,034	
946		Telephone and Telegrams	1,092	
370		Insurance	308	
315		Audit Fee—1957	250	
780		Sundry Payments	581	
8,717	11,305			
		Establishment Expenses:		
400		Rent	400	
1,558		Rates and Water	1,644	
2,200		Cleaning, Heating and Lighting	2,457	
310		Repairs and Decorations	275	
558		Office Furniture and Fittings	338	
5,026	5,114			
		Activities in connection with Publications (excluding Salaries and Overhead Charges):		
34,037		1958 Journal—Printing, Paper, etc.	35,208	
3,012		Other Activities—Expenses	2,923	
209		Adjustments—Amounts under-provided in previous year	437	
37,258	38,568			
		Library and Information Department:		
900		Library Books and Binding	898	
88		Reviewers' Fees	95	
816		Abstractors' Fees	829	
1,804	1,822			
		Miscellaneous:		
620		Historical Investigator—Honorarium and Expenses	630	
231		Contributions to Affiliated Local Societies	240	
180		Joint Committee for National Certificates in Metallurgy	230	
10		Prizes	10	
104		Grants	225	
1,145	1,335			
2,943		Balance carried down	—	
£97,964			£105,582	
—		Balance brought down	1,004	
628		Cost of Special Entertainment of Overseas Visitors	—	
842		Meeting on Air and Water Pollution	—	
1,801		Excess of Income over Expenditure for the year	158	
£3,271			£1,162	

INCOME

1957 £	£		£	£
		Subscriptions:		
16,804		Current	16,466	
427		Arrears	705	
17,231	17,171			
		Payments for Services other than Activities in connection with Publications:		
5,000		British Iron & Steel Research Association	5,000	
150		Andrew Carnegie Research Fund	150	
250		Mond Nickel Fellowship Committee	250	
1,000		Co-operative Translation Service	3,100	
6,400	8,500			
1,245	1,104	*Interest on Investments (gross)*		
6	5	*Deposit Account*		
		Institute of Metals:		
1,000		Library		1,000
1,566		*Rents Received*		1,550
5		*Sundry Receipts*		—
		Activities in connection with Publications:		
58,677		1958 Journal—Revenue	61,587	
11,834		Other Activities—Revenue	13,661	
70,511	75,248			
	1,004	Balance carried down		
£97,964	£105,582			
2,943	—	Balance brought down		
328	844	Refund of Superannuation Contributions less payments to former members of staff		
	318	Surplus on Meeting in Belgium		
£3,271	£1,162			

ACCUMULATED FUND, 31ST DECEMBER, 1958

1957 £		£
250	Transfer to Reserve for Comprehensive Index	250
1,000	,, ,, House Fund	1,000
500	,, ,, Reserve for Supplementing Staff Pensions	500
35,268	Balance carried to Balance Sheet	33,815
£37,018		£35,565

ASSETS

1957 £		£
28,939	Balance at 31st December, 1957	35,268
6,278	Transfer from Life Composition Fund	—
1,801	Excess of Income over Expenditure for the Year	158
—	Life Composition Fees received in 1958	139
£37,018		£35,565

HOUSE FUND—COST OF LEASE ACCOUNT

	£
Lease at Cost including Legal Expenses	43,518
Surveyor's Fees	460
Cost of Alterations to Library	579
	£44,557

	To 31st Dec., 1957	Current Year	Total
	£	£	£
Transfer from Accumulated Fund	5,000	1,000	6,000
Bank Deposit Interest	121	—	121
Interest on Investments	2,160	757	2,917
	7,281	1,757	9,038
Balance as per Balance Sheet			35,519
			£44,557

ANDREW CARNEGIE RESEARCH FUND

BALANCE SHEET, 31ST DECEMBER, 1958

1957		LIABILITIES		
£	£		£	£
	21,241	*Amount of Original Fund* $100,000	21,241	
	4,596	*Add:* Amount capitalised per last Balance Sheet	4,596	
25,837				25,837
		Sundry Creditors:		
	1,590	Grants	1,820	
	16	Audit Fee	16	
	161	The Iron and Steel Institute—Current Account	—	
1,767				1,836
2,600		*Reserve for Travelling Scholarships:*		2,600
		Accumulated Fund:		
6,406		Balance per Account annexed		4,796
£36,610				£35,069

1957		ASSETS		
£	£		£	£
34,746		*Investments at Cost as per Schedule* (Market Value 31st December, 1958, £32,982)		34,670
		Balance at Bank:		
	1,692	On Current Account	178	
	10	On Deposit Account	11	
	145	Post Office Savings Bank	149	
1,847				338
	17	*Sundry Debtor*—Income Tax Recoverable		61
£36,610				£35,069

ACCUMULATED FUND, 31ST DECEMBER, 1958

£			£	£		£	£
2,035		Grants	2,790	7,214	Balance at 31st December, 1957		6,406
150		Contribution to General Fund on account of Salaries	150		Income for the year ended 31st December, 1958:		
16		Audit Fee	16	1,393	Interest on Investments (gross)	1,422	
4		Medal	5	4	Interest on Deposits	4	
—		Loss on Redemption of 4% Conversion Stock	75	1,397			1,426
6,406		Balance carried forward	4,796				
£8,611			£7,832	£8,611			£7,832

WILLIAMS PRIZE FUND

BALANCE SHEET, 31ST DECEMBER, 1958

1957	LIABILITIES		1957	ASSETS	
£		£	£		£
2,220	*Capital Value* representing Market Value of £3,000 3½% Conversion Loan on 21st September, 1926 when the Fund was inaugurated	2,220	2,769	*Investments at Cost per Schedule* (Market Value at 31st December, 1958—£2,391)	2,769
561	Accumulated Fund—Balance per Account annexed	586		*Balance at Bank:*	
			12	On Current Account	37
£2,781		£2,806	£2,781		£2,806

ACCUMULATED FUND, 31ST DECEMBER, 1958

£			£	£		£	£
150		Awards	100	587	Balance 31st December, 1957		561
561		Balance carried forward	586		Income for the year ended 31st December, 1958:		
				121	Interest on 3½% Conversion Loan	121	
				3	Interest on Defence Bonds	4	
				124			125
£711			£686	£711			£686

BESSEMER MEDAL FUND

BALANCE SHEET, 31st DECEMBER, 1958

1957		LIABILITIES	£	£	1957		ASSETS	£	£
£					£				
	400	*Capital Value* representing Market Value of £400 4% Debenture of the L. & N.W. Railway	400			400	*Investments:* £474 15*s.* 0*d.* British Transport 3% Guaranteed Stock 1978/88	400	
900	500	*Grant* from the Iron and Steel Institute	500			500	£500 4% Funding Stock 1960/90 (Market Value 31st December 1958, £819)	500	
				900	900				900
42		*Accumulated Fund*—Balance per annexed Account		50	42		*Sundry Debtor:* The Iron and Steel Institute		50
£942				£950	£942				£950

ACCUMULATED FUND, 31st DECEMBER, 1958

£			£	£				£	£
26		Medal	26	34			Balance 31st December, 1957		42
42		Balance carried forward	50				*Income for year ended 31st December*, 1958		
					14		Interest on British Transport Stock	14	
				34	20		Interest on 4% Funding Stock	20	
								—	34
£68			£76	£68					£76

SIR ROBERT HADFIELD MEDAL FUND

BALANCE SHEET, 31st DECEMBER, 1958

1957	LIABILITIES	£	1957	ASSETS	£
£			£		
268	*Capital Value* representing Market Value of £267 11*s.* 2*d.* 3% Savings Bonds 1955/65	268	268	£267 11*s.* 2*d.* 3% *Savings Bonds* 1955/65 (Market Value at 31st December, 1958 £244)	268
44	Accumulated Fund—Balance per Account annexed	49	44	*Sundry Debtor*—The Iron and Steel Institute	49
£312		£317	£312		£317

ACCUMULATED FUND, 31st DECEMBER, 1958

£		£	£		£
3	Medal	3	39	Balance 31st December, 1957	44
44	Balance carried forward	49		Income for year ended 31st December, 1958:	
			8	Interest on 3% Savings Bonds	8
£47		£52	£47		£52

THE IRON AND STEEL INSTITUTE

SCHEDULE OF INVESTMENTS AT 31ST DECEMBER, 1958

SHOWING NOMINAL VALUES, COST, AND PRESENT MARKET VALUES

Nominal Value	Nature of Security	Market Value, 31st December, 1958	Cost Value
£ s. d.		£	£
GENERAL FUNDS OF THE INSTITUTE			
2,197 7 0	3½% War Stock	1,453	2,161
1,324 7 4	3½% Conversion Loan	879	1,254
2,954 19 0	4% Consolidated Stock	2,158	3,176
10,042 19 3	4% Funding Loan 1960/90	9,076	7,483
2,000 0 0	3% Savings Bonds 1955/65	1,824	2,000
5,000 0 0	do. 1955/65	4,559	4,972
2,000 0 0	do. 1960/70	1,614	2,000
1,500 0 0	do. 1965/75	1,175	1,500
4,854 2 0	British Transport 3% Guaranteed Stock 1978/88	3,750	5,407
		£26,488	£29,953
HOUSE FUND			
10,000 0 0	4% Funding Stock 1960/90	9,038	10,131
3,200 0 0	do.	3,000	3,251
2,200 0 0	do.	2,062	2,830
681 13 0	do.	639	600
196 10 1	do.	183	231
587 13 10	3½% Conversion Loan	390	513
205 15 6	3½% War Stock	136	212
2,615 11 2	British Transport 3% Guaranteed Stock 1978/88	2,052	1,893
		£17,500	£18,861
ANDREW CARNEGIE RESEARCH FUND (Trustees: The Hon. R. G. Lyttelton, N. H. Rollason, and W. F. Gilbertson)			
6,897 14 11	3½% War Stock	4,561	6,896
800 0 0	do.	529	794
2,693 12 0	3½% Conversion Loan	1,788	2,007
1,793 15 0	British Electricity 3% Guaranteed Stock 1968/73	1,386	1,762
4,166 18 7	4% Funding Stock 1960/90	3,766	4,676
500 0 0	4½% Defence Bonds (Conversion Issue)	500	500
17,812 10 3	British Transport 3% Guaranteed Stock 1978/88	13,760	10,863
1,000 0 0	3% Savings Bonds 1955/65	912	1,000
2,250 0 0	do. 1960/70	1,820	2,250
3,803 0 0	5½% Exchequer Stock 1966	3,960	3,922
		£32,982	£34,670
WILLIAMS PRIZE FUND (Trustees: The Hon. R. G. Lyttelton, N. H. Rollason, and W. F. Gilbertson)			
3,452 15 7	3½% Conversion Loan	2,291	2,670
100 0 0	3½% Defence Bond (Conversion Issue)	100	99
		£2,391	£2,769
SIR ROBERT HADFIELD MEDAL FUND			
267 11 2	3% Savings Bonds 1955/65	244	268
BESSEMER MEDAL FUND (Trustees: Desmond Lysaght, The Hon. R. G. Lyttelton, and N. H. Rollason)			
474 15 0	British Transport 3% Guaranteed Stock 1978/88	367	—
500 0 0	4% Funding Stock 1960/90	452	500
		£819	£500

(*Signed*) W. BARR
Hon. Treasurer

(*Signed*) K. HEADLAM-MORLEY
Secretary

We have examined the foregoing Balance Sheets and Income and Expenditure Accounts with the Books and Vouchers of the Institute and certify them to be correct. We have also verified the balances at the Bankers and the Securities for the Investments shown above.

FINSBURY CIRCUS HOUSE
BLOOMFIELD STREET, E.C.2
19th March, 1959

(*Signed*) W. B. KEEN & CO.
Chartered Accountants

PAPERS AND REPORTS ON RESEARCH AND PRACTICE

Metallurgy · Plant Operation · Research

Refining liquid pig iron in electric arc furnaces

By R. Durrer and G. Heintze

SYNOPSIS

The projected expansion of steel production in Switzerland has led to investigation of the possibilities of using local high-phosphorus ores in electric arc furnaces. Trials are described using up to 70% total charge-weight of low- and high-phosphorus pig irons, in 12- and 40-ton capacity arc furnaces, with ore as the main refining agent. Control of refining, use of full transformer capacity, and wear of refractories and electrodes are considered and results tabulated. Considerable increases in hourly output of electric arc furnaces are possible by the 'pig iron plus ore' process compared with all-scrap charging. Some experiments in direct steelmaking were also made by increasing the ore charge in the form of fines and adding coke fines to give a gain in finished steel. 1696

INTRODUCTION

SINCE its first industrial beginnings about the turn of the century, steelmaking in electric arc furnaces has steadily increased in importance. Steels of practically all compositions can be melted in electric arc furnaces. Until recently, however, they were primarily used for melting high-quality, particularly alloyed steels, since the conversion costs were considerably higher than with other steelmaking processes, because of the relatively high cost of electricity compared with natural fuels, the relatively small charge weights, and the long melting times. Only in countries where cheap hydro-electric energy was available, particularly Scandinavia and the Alpine countries, could tonnage steels be economically produced in arc furnaces.

Shortly after the Second World War, there were a few isolated instances in the USA of unalloyed low-carbon steels produced in arc furnaces, but it was soon found that in large modern furnaces, despite the rather higher electrical energy costs, the overall production costs could be reduced to such an extent as to make electric steelmaking competitive with the open-hearth process.

Recently, various investigations have been undertaken on the economics of steelmaking in arc furnaces compared with O H furnaces. The most comprehensive study is the report by the Battelle Memorial Institute,[1] in which it is stated that in the USA steels can be more cheaply produced in the arc furnace than in the O H, when a 100% cold charge is used. Other investigations[2–8] including some in European countries come to the same or similar conclusions. For many countries, however, reservations are expressed regarding this favourable estimate of electric steelmaking, because energy costs are still too high and the scrap supply is inadequate. Arc furnaces are mostly run on 100% cold charges. As is well known, however, O H furnaces can also be operated economically with high proportions of liquid pig iron, whereas insufficient experience is available on such charges for arc furnaces. Therefore the view seems justified that further development of electric steelmaking will be strictly limited so long as it is dependent on scrap supply, whilst O H furnaces enjoy a wider choice of raw materials. So long as neither the converter–arc-furnace duplex process nor the introduction of other cold-charge materials, such as sponge iron, can be considered as economical propositions, the direct refining of liquid pig iron, to the same extent as in the O H furnace, will continue to be the problem, the solution to which will open up new possibilities in electric steelmaking. The idea of transferring to the

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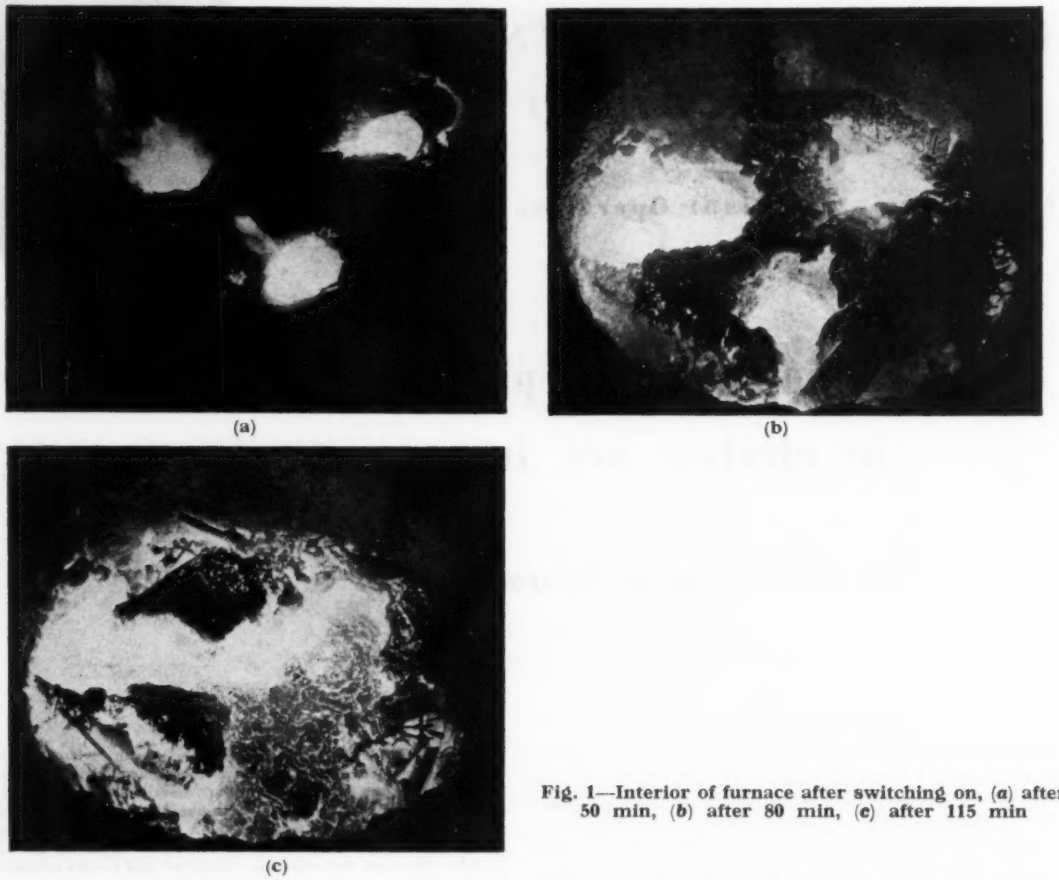


(a) (b) (c)

Fig. 1—Interior of furnace after switching on, (*a*) after 50 min, (*b*) after 80 min, (*c*) after 115 min

arc furnace the ' pig iron plus ore process ' used in O H practice is not new. As early as 1913, tests on these lines were carried out by Eilender.[9] In 1941, Berg[10] reported on the promising results obtained on charging liquid pig iron in a 6-ton Heroult furnace. More recent technical literature contains a number of references to attempts in US steelworks to handle pig iron instead of scrap in arc furnaces.[11–15] Various possible methods of carrying out the ore refining are indicated, but the associated difficulties are also noted and it is emphasized that none of these techniques has been accepted as a final solution by the steelworks, and that in particular there have been no disclosures made which describe the technique in detail.[16]

Ogan and Carney[17] at the International Steel Congress at Liège in June 1958 described experience with large arc furnaces in the USA. Regarding production costs for steel, these authors conclude that with 100% solid charge the arc furnace works better than the O H furnace, but when liquid pig iron is charged the latter is to be preferred. The authors review briefly the tests carried out in various steelworks to process liquid pig iron as 20–40% of the charge weight in arc furnaces. As against the difficulties which arose earlier, considerable improvements are said to have been achieved, and one can now charge up to 40% liquid iron without experiencing serious slag or steel spitting during refining. Nevertheless, the authors emphasize that US steelmakers have not so far found the best technique for processing liquid iron in an arc furnace. The production figures in the paper show that there is neither an increase in output nor a saving in energy when using 25–30% pig iron as against 100% cold charge.

The present paper is intended as a contribution to the direct refining of liquid pig iron in arc furnaces. Switzerland possesses no notable sources of natural fuel, but as electrical energy can be produced to a comparatively large extent from natural water resources steel is made exclusively in arc furnaces. The raw material basis has hitherto been the limited scrap arising within the country, so that the intended expansion of steel output can only be achieved by the roundabout method of producing pig iron from Swiss ores. The Fricktal ore considered for smelting resembles in composition the Minette ore of Lorraine and produces a pig iron of high phosphorus content. For economic reasons the basic Bessemer process, the oxygen-blowing process, and the O H process cannot be used, thus tests have been conducted in recent years, at the Gerlafingen (Switzerland) steelworks of Ludw. von Roll'schen Eisenwerke AG, to refine liquid pig iron, and in particular high-phosphorus pig iron, in the arc furnace. Within the framework of the tests

TABLE I

Changes in bath and slag composition during refining, with about 50% liquid high-phosphorus pig iron in the charge (cf. Figs. 1*a*–*c*)

Time, min	Operation/ Condition	Steel C, %	Steel P, %	Slag P_2O_5, %	Slag Fe, %	Notes
0	Switch-on	3·50	1·770	...	...	Composition of pig iron
50	Remove roof sample 1	2·28	0·570	16·75	17·90	Fig. 1*a*
85	,, ,, 2	1·58	0·275	14·47	10·82	Fig. 1*b*
115	,, ,, 3	0·92	0·030	15·00	18·30	Fig. 1*c*
140	Scrap all melted sample 4	0·68	0·025	14·81	17·30	...
150	Sample 5	0·58	0·035	13·77	13·38	...

reported in this paper, low- and high-phosphorus pig irons were charged as up to 70% of the total charge weight in 12-ton and 40-ton arc furnaces, using ore as the main refining agent.

PROBLEMS OF ORE REFINING IN ARC FURNACES

The main problem in using ore as the refining agent is control of the refining reaction at high refining rates. Continuous addition of ore in small quantities only permits carbon burn-off rates of about 0·3–0·5% C/h, which entails long heat times when large proportions of pig iron are used, together with a considerable drop in hourly throughput as compared with 100% solid charges. Charging large amounts of ore on to the furnace hearth or mixed with the solid charge materials can, as experience has shown, lead to non-uniform reactions associated with spontaneous ejection of slag and steel as soon as the bath has reached a high temperature. The formation of carbon monoxide involved in the oxidation of the carbon produces large volumes of waste gas which can only be removed from the furnace under control when the carbon burn-off occurs uniformly and can be controlled by adjusting the energy input.

Ogan and Carney[17] mention certain techniques which are used in the USA; these vary in the order of charging the various solid raw materials, e.g. scrap, lime, ore, and the liquid pig iron. However, the information is insufficient for a generally valid set of melting instructions to be deducible from it. Our own tests clarified the conditions under which the refining of pig iron with ore can be controlled in the arc furnace whilst avoiding the known difficulties and making full use of the transformer capacity throughout the entire refining process. Particular attention was also paid to dephosphorization of the pig iron.

PRINCIPLE OF THE OPERATING TECHNIQUE

When scrap and liquid pig iron are charged together, the arcs proceeding from the electrodes melt vertical cylindrical or crater-shaped channels into the scrap projecting up from the liquid metal bath surface and tend to make direct contact with the pig iron covering the furnace hearth. This takes place faster when there is less scrap. The channels widen gradually under the influence of the arcs and can be considered for a limited period as self-contained crucibles or melting vessels, their walls being

TABLE II

Characteristics of arc furnaces used

Characteristic	40-ton furnace	12-ton furnace
Electrode control	electric-hydraulic	electric-hydraulic
Nominal size, tons	30	12
Charge weight, tons	38–42	13–15
Transformer rating, kVA	18 000	3 500
Primary voltage, V	45 000	3 500
Secondary voltage, V	370/129	200/81
Electrode material	graphite	graphite
Electrode dia., mm	500	350
Secondary current per electrode, A	27 000	10 100
Method of charging	pan	pan
Inside dia. of casing, mm	5 200	3 200
Electrode pitch dia., mm	1 600	1 250

formed of scrap and their contents of liquid pig iron. As soon as the arcs reach the liquid pig-iron bath surface they try to form a closed circuit with the latter. Thus the heat produced is concentrated in a very confined space and is transmitted to the liquid metal. If the ore required to refine the pig iron is now added mainly in the immediate vicinity of the arcs playing on the bath, it enters into rapid and violent reaction with the accompanying elements contained in the pig iron. At the same time this reaction (at first locally confined) between the ore and the pig-iron carbon produces a pronounced effervescence in the slag formed; the arcs are completely covered and screened by it and subsequent rapid melting of the scrap is delayed. A considerable proportion of the heat produced by the arcs is expended in reduction of the ore by the accompanying elements in the pig iron. Further melting of scrap can only take place to a limited extent by the direct arc action and is mainly due to gradual heating from the already molten part of the charge in which the scrap is immersed. In this way not only is the reaction centre, where the energy input is high, screened off so that the furnace walls cannot be directly affected by radiation from the arcs, but also the scrap still to be melted acts as an independent temperature regulator. Under these conditions the carbon burn-off reaction can be controlled by direct adjustment of the energy input.

Ore can be charged into this gradually widening crucible either by direct charging or by suitable mixing in the solid charge, so that the ore is mainly contained in the vicinity of the crucibles as they form and is exposed to the direct arc action at an early stage. The lime required can be handled in the same way, so as to ensure early slag formation.

When, after a certain time, the three separate crucibles first formed by the arcs come to break down, the ore already added will have largely dissolved in the slag and much of it will have already been reduced. The bath continues to boil uniformly and the ferrous oxide content of the slag to fall correspondingly until the required initial carbon content is reached. By estimating the ore quantity as closely as possible, with reference to the pig-iron analysis, scrap

TABLE III
Composition and grain size of refining ores

Type of ore	Composition, %							Grain size
	Fe	CaO	SiO_2	MgO	Al_2O_3	P	S	
Itabira	68·1	Sp.	0·3	0·2	0·4	0·03	0·008	small lump to fine
Valais magnetite	61·8	1·7	5·0	0·6	n d	0·10	0·020	70% under 0·72 mm
Kiruna A	68·3	1·1	2·3	0·8	n d	0·04	0·004	small lump to fine
Kiruna B	58·9	4·7	3·6	0·7	n d	1·86	0·020	,, ,, ,, ,,

n d = none detected

composition, and the extent to which the scrap is oxidized, the desired initial carbon content can be achieved with sufficient accuracy. The heat is finished in any required manner, as with ordinary scrap heats. When high-phosphorus pig iron is charged, the phosphate slag is removed at a higher carbon content and refining completed under a second low-phosphorus slag. When low-phosphorus pig iron is charged, the amount of ore can be estimated so that the initial carbon content is only a few points below the required final content and only a short time is needed to finish the heat.

Figures 1*a–c* illustrate the progress of a heat with about 50% liquid high-phosphorus pig iron in the charge. During melt-down and refining, the furnace roof was removed at various intervals of time to photograph the inside of the furnace, steel and slag samples being taken at the same time to follow the progress of the refining reaction. Table I gives the timetable for the heat, with the corresponding bath and slag analyses. It must be pointed out in connection with this table that, because of the refining process being repeatedly interrupted and because of the heat losses due to removing the roof, the melting time was considerably increased.

Figure 1*a* shows the furnace contents 50 min after switching on the power. The topmost scrap layer is still almost as high as at the beginning of the melt. Clearly not much scrap has been melted down as yet. The refining reaction has, however, already become lively and the carbon content of the liquid fraction of the charge has fallen to 2·28%, with the phosphorus at 0·570%. The slag sample taken with the steel sample shows the high phosphorus content of 16·75%.

After this first sampling, the heat was continued for 35 min at full power input. Figure 1*b* shows the furnace contents when the second samples were then taken. The solid charge has fallen uniformly and the crucibles melted out by the arcs have widened considerably. The steel analysis was 1·58%C and 0·275% P with the phosphoric acid content of the slag somewhat lower at 14·47%.

Figure 1*c* shows the inside of the furnace after a further 30 min under power. The scrap has sunk further, although three peninsula-like aggregates of scrap, which will obviously soon sink into the bath, can still be clearly seen. At this stage the bath contained 0·92%C and 0·030%P. The P_2O_5 content of the slag, at 15·0%, was about the same as in the previous sample. In spite of the high P_2O_5 content of the slag, dephosphorization had been carried to this low level in the presence of the high carbon content.

After taking this sample the charge was heated a further 25 min. The bath continued to boil under the still ferrous-oxide-charged slag, and reached a carbon content of 0·69%, with a phosphorus content of 0·025%. At this time the slag again showed a practically unchanged P_2O_5 content of 14·81%. When this sample was taken all the scrap had been melted down. After carefully removing the slag and adding lime to form a second low-phosphorus slag this heat was finish-refined with gaseous oxygen.

TABLE IV
Charge data up to first sampling, 12- and 40-ton arc furnaces

Group no.	No. of heats	Furnace capacity, tons	Metal charge, kg	Pig-iron proportion, %	Pig iron analysis, %					Steel analysis, % (1st sample)				Switch-on to 1st sample		
					C	Si	Mn	P	S	C	Mn	P	S	Time, min	Output rate, t_E/h	Energy, kWh/t_E
1	10	12	11 515	0	...	...	...	...	...	0·34	0·26	0·047	0·046	125	5·6	474
2	3	,,	14 740	51·5 (low P)	3·92	1·44	0·87	0·085	0·035	0·57	0·11	0·057	0·043	110	8·1	340
3	173	,,	13 880	48·1 (high P)	3·56	0·55	0·64	1·840	0·041	0·42	0·19	0·060	0·028	112	7·5	384
4	155	40	40 900	0	...	...	...	...	...	0·31	0·33	0·049	0·061	97	25·2	456
5	82	,,	40 656	47·1 (low P)	3·44	0·69	0·50	0·111	0·051	0·38	0·14	0·036	0·052	70	34·7	328
6	41	,,	40 257	46·8 (high P)	3·33	0·79	0·38	1·370	0·055	0·32	0·16	0·037	0·040	74	33·1	348
7	12	,,	36 900	49·4 (low P)	3·63	0·72	0·63	0·125	0·047	0·22	0·18	0·021	0·041	54	41·0	344

t_E = tons charged

TABLE V
Furnace data, charging with 100% solid charge, and 50% liquid pig-iron charge

Melting charge composition	Charge wt., tons	Hearth dia., m	Transformer rating, kVA	Maximum melt-down voltage, V	Melting rate, tons/h	Remarks
100% solid	12·5	3·8	5 000	220	6·6	after Pakulla
,, ,,	11·5	3·2	3 500	200	5·6	von Roll
50% liquid pig-iron, low P	14·7	3·2	3 500	200	8·1	von Roll
50% liquid pig-iron, high P	13·9	3·2	3 500	200	7·5	von Roll
100% solid	35·0	5·2	9 000	270	11·5	after Pakulla
,, ,,	73·0	5·7	15 000	340	17·9	,, ,,
,, ,,	40·9	5·2	18 000	370	25·2	von Roll
50% liquid pig-iron, low P	36·9	5·2	18 000	370	41·0	von Roll
50% liquid pig iron, high P	40·3	5·2	18 000	370	33·1	von Roll

FURNACES AND RAW MATERIALS

Table II gives the most important characteristics of the arc furnaces. The furnaces have silica roofs which lift or slide off and are roof-charged. The hearths are rammed with powdered dolomite by the Crespi process, and the walls are built up with 'Dolo-Sinter' blocks by the Crespi Jr. process.

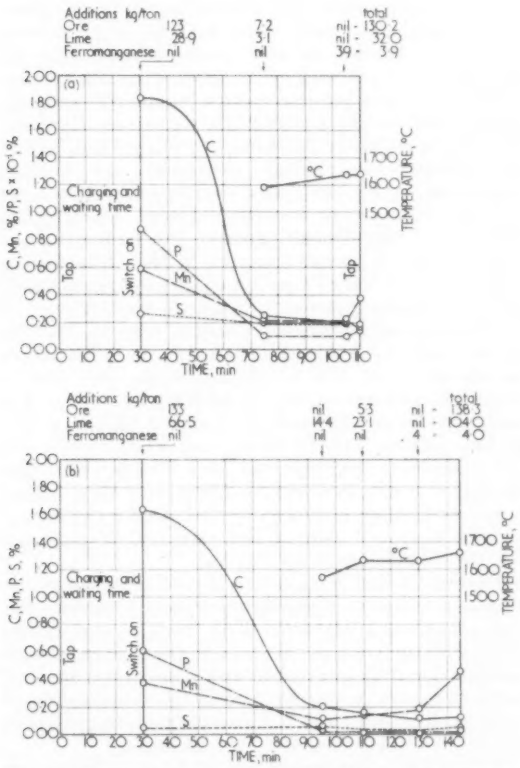


Fig. 2—Curves for a heat in the 40-ton arc furnace, charged with (*a*) 50% low-phosphorus liquid pig iron, charge no. 52895, (*b*) 50% high-phosphorus pig iron, charge no. 51494

Table III gives data on the composition and particle size of the refining ores. In some heats, millscale was also used as the refining agent. Typical pig iron compositions are contained in Tables IV and VIII. The temperature of the pig iron on charging into the furnace was about 1 250–1 300° C.

OPERATIONAL RESULTS

The overall melting time for a heat, reckoned from tap to tap, can be divided into three stages, the durations of which are influenced by different factors:

(1) *Charging and intermediate time*—Largely independent of the metallurgical process, and its duration is essentially determined by the mechanical operating equipment.
(2) *Melt-down time*—Largely determined by the possible energy input per unit time, i.e. by the transformer capacity.
(3) *Time for finishing the heat*—Under otherwise similar conditions this can vary according to the quality requirements to be met.

In comparing different arc furnace melting techniques, i.e. in this case in comparing the all-scrap technique with the pig iron plus ore technique, one must first consider the melt-down times, the melting rates, and the corresponding energy consumption associated therewith. In the following, the times up to taking the first sample are compared for the two methods of working (the all-scrap technique and the pig iron plus ore technique), the first sample being taken with the melts in roughly the same condition. In the pig iron plus ore technique, the meltdown time includes melting the scrap and refining the pig iron. The finishing of the heat should then require about the same time for similar steel qualities, so long as the preceding refining period in the pig iron plus ore technique exerts no decisive influence on the further metallurgical progress of the melt until it is tapped.

Table IV, in addition to giving data on the charge, the pig iron composition, and the steel composition at the first sampling, gives the melt-down time (from switch-on to first sample), the melting rate calculated from the latter, and the corresponding energy consumption for charges with around 50% liquid pig iron, against the results for 100% scrap charges.

TABLE VI

Charge data for a 40-ton arc furnace heat with 50% liquid low-P pig iron in the charge (heat no. 52895)

	Total charge, kg	Molten yield, kg/ton	Metal charged (scrap + pig), %	Total metal content (scrap + pig + Fe from ore + FeMn), %
Charge				
Scrap	17 000	491·5	50·0	45·7
Liquid pig iron	17 000	491·5	50·0	45·7
Total metal charged	34 000	983·0	100·0	91·4
Fe from 4 500 kg ore (68%Fe)	3 065	88·5	9·0	8·2
Ferromanganese	135	3·9	0·4	0·4
Total metal content of charge	37 200	1 075·4	109·4	100·0
Lime	1 110	32·0	3·3	3·0
Yield				
Molten steel	34 600	1 000·0	101·8	93·0
Burn-off	2 600	75·4	7·6	7·0
	37 200	1 075·4	109·4	100·0

TABLE VII

Charge data for a 40-ton arc furnace heat with 50% liquid high-P pig iron in the charge (heat no. 51494)

	Total charge, kg	Molten yield, kg/ton	Metal charged (scrap + pig), %	Total metal content (scrap + pig + Fe from ore + FeMn), %
Charge				
Scrap	19 500	518·0	52·3	47·7
Liquid pig iron	17 800	474·0	47·7	43·6
Total metal charged	37 300	992·0	100·0	91·3
Fe from 5 200 kg ore (65%Fe)	3 370	89·6	9·0	8·3
Ferromanganese	150	4·0	0·4	0·4
Total metal content of charge	40 820	1 085·6	109·4	100·0
Lime	3 910	104·0	10·5	9·6
Yield				
Molten steel	37 600	1 000·0	100·8	92·0
Burn-off	3 220	85·6	8·6	8·0
	40 820	1 085·6	109·4	100·0

Of the heats melted in the 12-ton arc furnace (groups 1–3) special mention should be made of those with high-phosphorus pig iron, since low-phosphorus pig iron was only used in a few tests. The phosphorus content of the pig iron was 1·84%, as the average of 173 heats made in the course of production; against this the first steel samples showed 0·060%P with an average carbon content of 0·42%. Despite the considerable energy consumption in dephosphorization, the melting load (7·5 tons/h) is about 32% higher than for the all-scrap heats quoted for comparison. It should also be noted that the scrap heats were subject to special observation as test heats, and the results achieved were thus even better than could be expected in the course of normal production. The energy consumption to meltdown, at 384 kWh/ton, is 23% lower than with an all-scrap charge. The three heats with low-phosphorus pig iron in the charge show even somewhat better results.

In the tabulated results obtained in the 40-ton arc furnace groups (4–7), the average values for 82 successive heats with low-phosphorus and 41 with high-phosphorus pig iron are again compared with results from all-scrap operation. The carbon and phosphorus contents of the first samples varied little. Against the 100% scrap heats, a reduction of about 29% in energy consumption is obtained when charging 50% liquid low-phosphorus pig iron and about 23% with high-phosphorus pig iron. The melting rate is correspondingly 37% and 32% higher.

With these 40-ton arc furnace heats made in continuous production conditions, account had to be taken of major variations in pig-iron composition and weight, because at the time of the tests the steelworks did not have a mixer available. Exact estimation of the ore and lime additions was thereby greatly complicated. Moreover, there was often delay in delivering the pig iron, leading in most cases to a corresponding extension of the melt-down time. The results, which must nevertheless be regarded as favourable, thus do not represent the optimum attainable with better working arrangements. In group 7 therefore, the averages are again given for 12 heats made under what corresponds to normal working conditions. In spite of the reduced average charge weight of only 36·9 tons, the melting rate of 41·0 tons/h is 63% higher than for all-scrap operation, whereas the energy consumption of 344 kWh/ton is about the same as for the heats given under groups 5 and 6.

Table V gives the hearth diameters, charge weights, transformer capacities, and maximum melt-down voltage for the arc furnaces at Gerlafingen, and the melting rates achieved with 100% solid charge and with 50% liquid pig-iron charge, compared with the values published by Pakulla[18] for various arc furnaces. Bearing in mind the differences in charge weight and the different transformer capacities, the melting rates achieved for 100% solid charges in the 12-ton arc furnace are more or less comparable. The decisive influence of transformer capacity can be seen in the example of the 40-ton furnace. With a transformer capacity of 18 000 kVA and a charge weight of about 41 tons, a melting rate of 25·2 tons/h was achieved at Gerlafingen on 100% scrap charges, whereas Pakulla quotes only 17·9 tons/h for a furnace with larger hearth diameter and a 73-ton charge, but with a lower transformer rating of 15 000 kVA. Thus the melting rates reached with 50% liquid pig iron in the 40-ton furnace (18 000 kVA), i.e. 41·0 tons/h for low-phosphorus pig iron and 33·1 tons/h with high-phosphorus, are as much as 138% and 86% higher respectively than is quoted by Pakulla for the 70-ton furnace equipped with a less powerful transformer (15 000 kVA) working on all scrap.

Figures 2*a* and *b* show the course of heats in the 40-ton arc furnace charged respectively with low- and high-phosphorus pig iron. The initial compositions plotted on the vertical axis refer to the average charge compositions (pig iron and scrap). The carbon burn-off curves were drawn to approximate the actual course of refining. Tables VI and VII give the material balances for the two heats shown in Figs. 2*a* and *b*.

Tables VIII*a* and *b* show typical heats in the 40-ton arc furnace, with complete data on charge, melting time, energy consumption, and the final steel composition. The data on charges with about 50% liquid low-

TABLE VIII*a*

Test data on some 40-ton arc furnace heats

Serial no.	Charge no.	Pig iron and scrap, kg	Pig iron, %	Ore, %	Fe in ore, kg	Ferro-manganese, kg	Total metal charged, kg	Lime, kg	Gaseous oxygen, m^3/ton (NTP)	Pig-iron analysis, % C	Si	Mn	P	S
Low-P pig iron														
1	51980	35 300	49·0	4 000	2 600	180	38 080	860	1·31	3·75	0·94	0·40	0·085	0·056
2	51996	35 000	48·6	4 500	2 925	200	38 125	1 500	...	3·70	0·49	0·56	0·100	0·054
3	52768	33 500	49·3	4 250	2 600	120	36 220	1 170	...	3·50	0·56	0·53	0·165	0·048
4	53063	34 500	50·7	4 250	2 900	165	37 565	1 450	...	3·50	0·68	0·55	0·110	0·126
5	52895	34 000	50·0	4 500	3 065	135	37 200	1 110	...	3·55	0·89	0·76	0·125	0·012
High-P pig iron														
6	51486	36 700	47·4	5 450	3 530	160	40 390	3 790	...	3·35	0·89	0·41	1·350	0·040
7	51494	37 300	47·7	5 200	3 370	150	40 820	3 910	...	3·30	0·61	0·34	1·200	0·048
8	51495	37 800	48·4	5 100	3 310	180	41 290	3 210	...	3·40	0·61	0·38	1·260	0·032
9	51463	38 500	50·9	6 400	4 150	160	42 810	2 470	...	3·00	0·75	0·37	0·650	0·088
10	51467	34 800	45·7	5 600	3 640	205	38 645	3 070	...	3·10	0·88	0·39	1·250	0·080
100% scrap														
11	53397	41 000	...	500	300	190	41 490	920	2·66	...	...	...	...	...
12	53420	41 000	...	200	120	160	41 280	1 020	2·67	...	...	...	...	...
13	53422	41 000	...	350	210	180	41 390	720	2·42	...	...	...	...	...
14	53444	41 000	...	200	120	190	41 310	660	4·60	...	...	...	...	...
15	53448	41 200	...	200	120	180	41 500	970	3·80	...	...	...	...	...

TABLE VIII*b*

Test data on some 40-ton arc furnace heats

Serial no.	Heat no.	Charging and waiting time, min	Melting time: Switch-on to 1st sample, min	Melting time: 1st sample to tap, min	Tap to tap, min	Output rate and energy consumption: Switch on to 1st sample t_E/h	kWh/t_E	Tap to tap t_R/h	kWh/t_R	Steel analysis, % C	Si	Mn	P	S
Low-P pig iron														
1	51980	30	50	45	125	45·5	342	16·8	520	0·08	...	0·41	0·023	0·036
2	51996	30	55	40	125	41·5	390	16·8	537	0·08	...	0·42	0·012	0·034
3	52768	30	53	32	115	40·8	375	17·4	458	0·15	0·13	0·46	0·040	0·020
4	53063	30	50	30	110	44·9	348	18·8	463	0·10	0·13	0·42	0·010	0·034
5	52895	30	46	34	110	48·3	337	18·7	460	0·17	0·11	0·37	0·025	0·018
High-P pig iron														
6	51486	30	65	60	155	37·1	329	14·4	490	0·12	0·13	0·40	0·023	0·022
7	51494	30	65	50	145	37·5	331	15·5	471	0·12	0·14	0·45	0·015	0·030
8	51495	30	80	45	155	30·8	333	14·7	489	0·16	0·15	0·40	0·015	0·024
9	51463	30	73	62	165	35·1	394	14·3	564	0·14	0·18	0·39	0·025	0·022
10	51467	30	65	55	150	35·6	413	14·2	538	0·15	0·18	0·40	0·020	0·020
100% scrap														
11	53397	30	105	70	205	23·6	454	11·2	615	0·05	...	0·37	0·013	0·036
12	53420	30	125	60	215	19·8	498	10·6	654	0·08	...	0·35	0·015	0·040
13	53422	30	110	55	195	22·5	451	11·7	624	0·10	...	0·42	0·025	0·030
14	53444	30	130	70	230	19·0	447	9·9	610	0·09	...	0·44	0·028	0·048
15	53448	30	100	65	195	24·8	403	11·7	570	0·05	...	0·38	0·020	0·038

t_E = tons charged
t_R = tons of molten steel

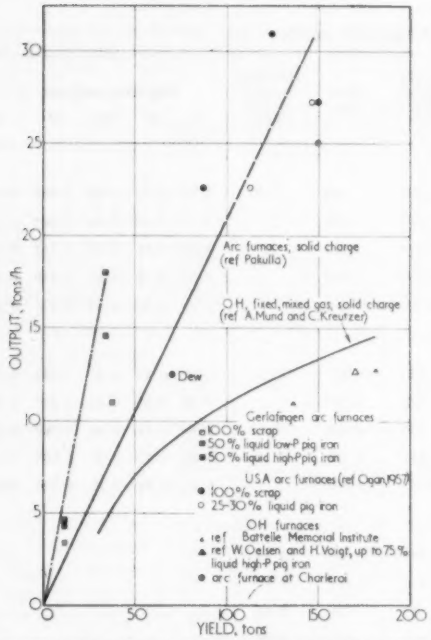

OUTPUT, tons/h
YIELD, tons
Arc furnaces, solid charge (ref Pakulla)
O H, fixed, mixed gas, solid charge (ref A Mund and C Kreutzer)
Dew
Gerlafingen arc furnaces
100% scrap
50% liquid low-P pig iron
50% liquid high-P pig iron
USA arc furnaces (ref Ogan/Rist)
100% scrap
25–30% liquid pig iron
OH furnaces
ref Battelle Memorial Institute
ref W Oelsen and H Voigt, up to 75% liquid high-P pig iron
arc furnace at Charleroi

Fig. 3—Hourly outputs for arc furnaces charging 100% scrap and large proportions of liquid pig iron, compared with fixed O H furnaces

and high-phosphorus pig iron were compared with those on charges with 100% solid scrap. As can be seen from these examples, whilst with 100% solid charges the hourly throughput is about 9·9–11·7 tons/h (tap to tap), it can be raised to over 15 tons/h with 50% liquid high-phosphorus pig iron and even to over 18 tons/h with low-phosphorus.

The decisive factor in the increased output for charges with high proportions of liquid pig iron is mainly the shortened melt-down time to the first sample. The finishing of the heat proceeds in the normal manner for the arc furnace, irrespective of the type of charge. When liquid pig iron is charged, lively boiling takes place during the melt-down, associated with extensive dephosphorization and desulphurization, so that the finishing time can also be curtailed without deleterious effects on steel quality. The times shown in Table VIII*b* from first sample to tap show that with all-scrap charges 64 min was required on average for finishing, whilst with low-phosphorus pig iron in the charge, finishing averaged 36 min.

With this increase in output is associated a notable reduction in energy consumption, namely about 17% for heats with high-phosphorus pig iron in the charge and about 21% in the case of low-phosphorus pig iron. These energy consumption figures, like those for hourly output, refer to the molten steel yield.

Figure 3 shows the hourly outputs for arc and O H furnaces, as a function of furnace size (yield in tons). In this figure the values published by Pakulla,[18] based on output figures from arc furnaces at Deutsche Edelstahlwerke and on data from the Battelle Memorial Institute Report,[1] are amplified by our own test

TABLE IX

Waste-gas analysis during ore refining in an arc furnace

Heat no.	Analysis, %					Remarks
	CO	CO_2	O	H	Total	
54988	30·9	16·8	4·1	6·8	58·6	Slight refining (start)
54988	70·1	16·3	2·1	1·1	89·6	Main refining period
55072	80·4	9·1	1·7	1·0	92·2	,, ,, ,,
55072	78·6	8·4	1·6	1·1	89·7	,, ,, ,,
55072	34·9	16·5	0·4	0·5	52·3	Slight refining (end of refining period)

results and by more recent data on large arc furnaces[17, 19] and O H furnaces operating on the pig iron plus ore technique. The hourly outputs for the 40-ton arc furnace operating with about 50% liquid pig iron are higher than for the 200-ton O H furnace and roughly correspond to the good results on 70-ton arc furnaces operating on 100% solid charge.

The consumption of *refining ore* depends largely on the pig-iron composition, the desired final carbon content, and (by no means least) the oxygen content of the ore itself. If a rich hematite ore is used, one can estimate at about 220–290 kg ore per ton of pig iron. Using magnetite ore, the ore consumption is correspondingly higher. The degree of oxidation of the scrap can greatly influence the ore consumption.

The types of ore described in Table III were all suitable as refining agents, as was the millscale used occasionally. In every case a rich ore is preferable, because the amount of slag is increased by all the ore impurities and the lime consumption is higher. The high-phosphorus Kiruna ore, containing only about 59% Fe, was used without harmful results in heats with high-phosphorus pig iron. One particular advantage found with the technique adopted was that it is possible to use fine ores.

The iron pickup from the ore depends on the proportion of pig iron in the charge and the ore required per ton of pig iron. With pig-iron proportions of about 50–70%, the iron pickup was between 8 and 12% of the weight of metal charged.

The yield of metal was closely observed during the series of tests. Taking into account the iron contained in the ore, the molten metal yield averaged between 92 and 94%. Referred to the metallic charge alone (pig iron and scrap) this gave a yield of about 101–103%, corresponding to an iron pickup from the ore of about 9%. This high yield is of particular importance when the technique is evaluated from the point of view of economics.

The lime consumption is greatly influenced by the pig-iron composition. Melts with pig iron low in phosphorus and silicon content under 1·0% required on average 32 kg/ton of steel. When the pig iron contained more silicon and more desulphurization was required, the lime requirement rose to over 50 kg/ton of steel. When phosphorus-containing pig iron is used, the lime addition for the dephosphorizing slag is reckoned at about the same as in the basic Bessemer process, i.e. about 12–15% of the weight of pig iron. The usual quantity of lime, namely 2–3% of the weight

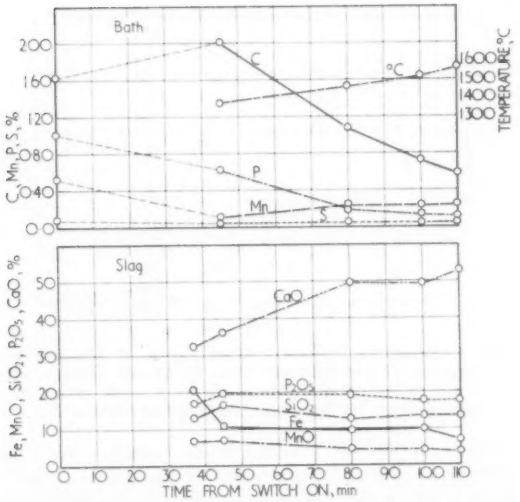


Fig. 4—Refining in 12-ton arc furnace with about 50% liquid high-phosphorus pig iron in the charge, charge no. 54988

of the charge, suffices for the low-phosphorus second slag.

The electrode consumptions, each referring to a furnace campaign of several weeks, were 5·5 kg/ton of steel in the 12-ton arc furnace, and 4·9 kg/ton of steel in the 40-ton arc furnace. These figures include electrode breakages, which in any case are slight with these high proportions of liquid pig iron, and with a little care can be avoided altogether.

In the test series carried out in the 12-ton and 40 ton arc furnaces, wall lives of 163 and 137 heats respectively were attained. The roof lives were 101 and 105 heats respectively. The hearth, which normally lasts for over 1 000 heats, showed no particular wear during the tests. There is reason to hope, however, that with increasing operational experience and more regular charges, even longer refractory lives can be achieved.

The results so far described were obtained charging

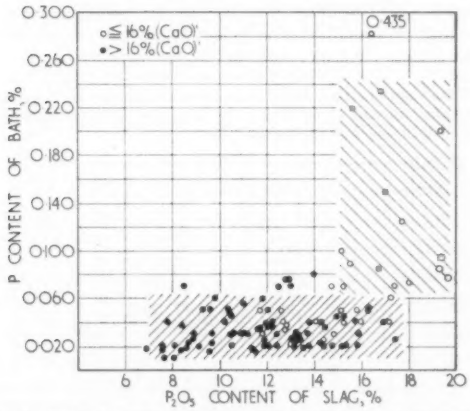


Fig. 5—Phosphorus content of the bath as a function of the P_2O_5 content of the slag at the time of taking the first sample, 12-ton arc furnace, 50% liquid high-phosphorus pig iron in the charge, 111 heats

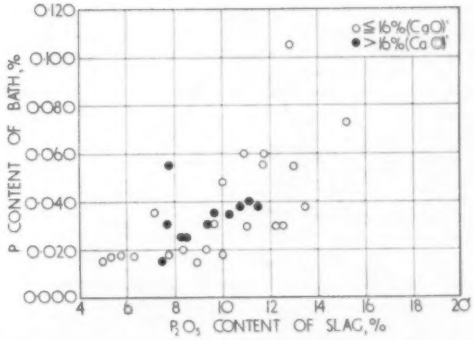


Fig. 6—Phosphorus content of the bath as a function of the slag at the time of taking the first sample, 40-ton arc furnace, 50% liquid high-phosphorus pig iron in the charge, 33 heats

about 50% liquid pig iron. In a few heats, the pig-iron proportion was raised to 70%. The results correspond more or less to those with 50% liquid pig iron.

METALLURGICAL CONSIDERATIONS

Carbon

The oxidation of the carbon contained in the pig iron is the main problem in refining pig iron in the arc furnace, since the product of the oxidation is gaseous and must be removed from the furnace at a relatively high temperature.

The carbon burn-off rate, which has a decisive influence on the duration of the heat, is determined by the quantity of oxygen introduced per unit of time. However, since the reaction between the ore and the carbon is strongly endothermic, the carbon burn-off rate in the presence of sufficient ore becomes a function of the electrical energy supplied per unit of time.

When, as in the examples quoted, the refining time is kept below 1 h with about 50% liquid pig iron in the charge, the mean carbon burn-off rate can be

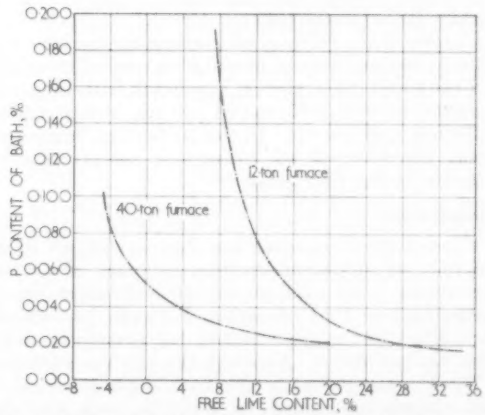


Fig. 7—Effect of the free lime content of the slag on the phosphorus content of the bath at the time of taking the first sample, about 50% liquid high-phosphorus pig iron in the charge; 40-ton furnace, 33 heats; 12-ton furnace, 111 heats

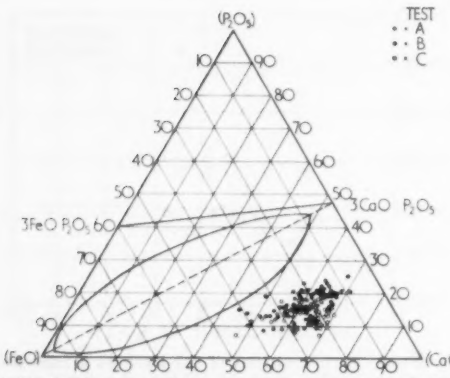


Fig. 8—Slag composition at the time of taking the first sample, about 50% liquid high-phosphorus pig iron in the charge, 144 heats

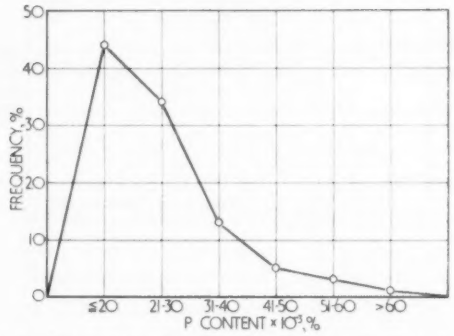


Fig. 9—Frequency distribution curve of phosphorus content of the finished steel from 144 heats under continuous production conditions with about 50% liquid high-phosphorus pig iron, 144 heats

reckoned at about 2%C/h. Considering only the pig iron in the charge, this corresponds to a mean carbon burn-off rate, for the pig iron, of about 3%C/h. In Figs. 2*a* and *b* it was shown that carbon burn-off does not proceed uniformly during the refining period. In the first 10–15 min it is relatively low, reaching its maximum during the next 25–30 min and falling off again towards the end of refining. Roughly 75% of the carbon is oxidized within about 25 min. In this period one must assume a mean carbon burn-off rate of about 3%C/h, referred to the total charge, and a true rate of about 6%C/h for the pig iron. According to the size and degree of utilization of the transformer capacity, the variable carbon content of the pig iron, and the variable pig iron proportion used, deviations from these values are possible.

When carbon is oxidized, considerable volumes of carbon monoxide are formed. For the types of charge described, and with the carbon burn-off rate held high, it was necessary to reckon with the evolution of about 0·5 m³/s (NTP) of CO during the main refining period. The gas issuing from the furnace during this period contained about 70–80%CO. Table IX shows the waste-gas compositions at various stages in the refining period.

In spite of the refining rates attained when the high transformer capacity of 18 000 kVA was fully utilized, and the rapid gas evolution associated with them, the reaction between refining ore and pig iron proceeded uniformly and quietly. In the 40-ton arc furnace the waste gas was led off through a special chimney attached to the furnace roof.

Phosphorus

When high-phosphorus pig iron is charged in the arc furnace, dephosphorization becomes of decisive importance. An example of dephosphorization, in comparison to that of carbon burn-off, has already been given in the discussion of the principles underlying the technique. Although the pig iron contained 1·77%P, at 0·92%C in the bath dephosphorization had already proceeded to 0·030%, with the slag loaded up to 15%P_2O_5. Thus under these working conditions, dephosphorization can be made largely to precede carbon burn-off.

Figure 4 shows the burn-off of the accompanying elements in the pig iron, in detail, together with the changes in slag composition during the refining period. With a charge containing about 50% pig iron of phosphorus content 1·96%, the amount of lime used was 13·7% of the weight of pig iron. At the end of the refining period the slag contained 17·40%P_2O_5 and 6·41%Fe, and the bath 0·58%C and 0·100%P. The bath temperature was 1 565° C.

Table IV gives the mean compositions of the pig iron and of the first steel samples for 173 heats in the 12-ton furnace and 41 heats in the 40-ton furnace. When these are compared with corresponding samples for heats made with low-phosphorus pig iron and with 100% scrap, it can be seen that, in spite of the high phosphorus content of the pig iron, that of the steel is at about the same low level. Bearing in mind the short refining period and the low energy consumption, this result is very satisfactory.

Figures 5–7 show the phosphorus contents reached in the bath at the time of taking the first sample, as a function of the P_2O_5 and free lime contents of the slag.* With increasing free lime content or decreasing P_2O_5 content in the slag, definitely lower phosphorus contents were found in the steel. Better dephosphorization was obtainable in the 40-ton arc furnace for comparable free lime contents in the slag. Apparently the higher specific transformer capacity has a favourable influence here, causing more intense and more

* In calculating the free lime content of the slag, phosphorus was assumed to be combined as triphosphate and silicon as orthosilicate.

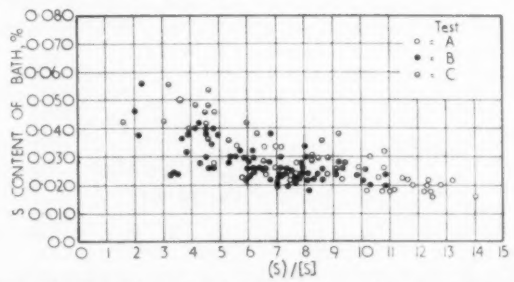


Fig. 10—Partition of sulphur between slag and bath at the time of taking first sample, using about 50% liquid high-phosphorus pig iron, 136 heats

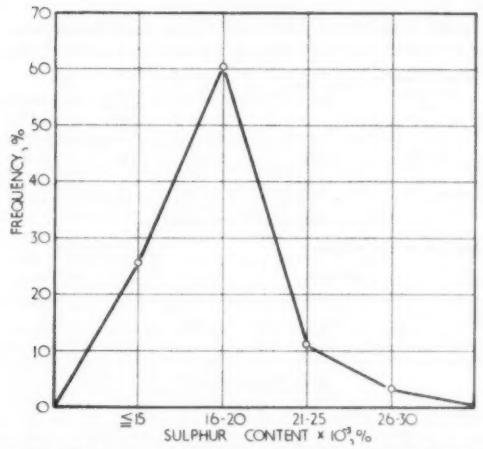


Fig. 11—Frequency distribution curve of sulphur content in the finished steel from 149 heats under continuous production conditions with about 50% liquid high-phosphorus pig iron

uniform reaction between slag and bath. The shape of the curve in Fig. 7 was based on the calculated mean values for the heats. Almost all the steel and slag samples were taken at the relatively low bath temperatures of 1 520–1 590° C. The effect of temperature in this range is slight and overshadowed by the variations in free lime and P_2O_5 content in the slag.

Figure 8 shows the position of the slags corresponding to the first samples in the FeO–CaO–P_2O_5 ternary system. These three slag components were recalculated to 100% and the FeO content was worked out from the total iron content.

The slags rich in P_2O_5 were normally removed after the first sample to eliminate the remaining carbon after replacing with a second highly basic slag and to finish the heat in the normal way. This also facilitates further dephosphorization down to very low levels. The composition of the first phosphorus-rich slag suggests that it may find use as a fertilizer. Investigations of the citric acid solubility of these slags are in progress.

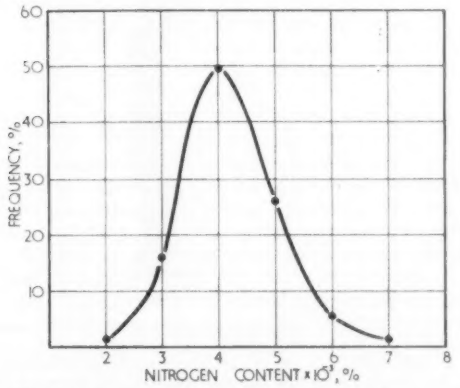


Fig. 12—Frequency distribution curve of nitrogen content in 69 unkilled heats after casting

TABLE X
Material balance for a 40-ton arc furnace heat with additional smelting of ore fines and coke fines, heat no. 52597, 23·1% Fe gain from ore

	Total charge, kg	Metal yield, kg ton	Pig iron + scrap charged, %	Total metal content (scrap + pig + Fe from ore + FeMn), %
Charge				
Scrap	15 500	445·0	50·3	40·6
Liquid pig iron	15 300	438·0	49·7	40·1
Total metal charged	30 800	883·0	100·0	80·7
Fe from 10 000 kg ore (68% Fe)	7 130	204·4	23·1	18·7
Ferromanganese	230	6·6	0·8	0·6
Total metal content of charge	38 160	1 094·0	123·9	100·0
Lime	1 400	40·2	4·6	3·7
Coke fines	1 900	54·5	6·2	5·0
Yield				
Molten steel	34 880	1 000·0	113·3	91·4
Burn-off	3 280	94·0	10·6	8·6
Total	38 160	1 094·0	123·9	100·0

Figure 9 shows the frequency distribution curve for the final phosphorus contents reached in the finished steel (tap samples), for 144 successive heats. In spite of the high phosphorus content in the pig iron, namely 1·8%, over 75% of all heats contained less than 0·030%P. In the few heats with higher phosphorus contents the slag was not removed adequately, so that the increased P_2O_5 in the finishing slag led to ready phosphorus reversion as the temperature was raised. In the 40-ton furnace similar results were attained. Typical phosphorus contents are given in Table VIII*b*.

Sulphur

Desulphurization in the arc furnace causes no particular problems. When high-phosphorus pig iron was charged, however, desulphurization during the refining period was found to be clearly superior to the case when low-phosphorus pig iron was charged. Figure 10 shows the sulphur content of the bath as a function of the sulphur partition between slag and bath. The samples come from three test series with high-phosphorus pig iron and different amounts of lime in the charge. The differences in mean free lime content of the slags compare as follows:

Test series	*Furnace capacity, tons*	*Free lime content, %(CaO)'*
A	12	23·55
B	12	17·90
C	40	12·98

In group A, with the highest mean free lime content, were found the highest partition coefficients and the lowest sulphur contents for the steel.

Using highly basic finishing slags practically any sulphur limit requirement can be met in the arc furnace. Figure 11 shows the frequency distribution curve for the final sulphur contents reached when charging high-phosphorus pig iron. In the majority of the heats it was possible to get below 0·020%S, despite the relatively high sulphur contents of pig iron and scrap. In the 40-ton arc furnace, a considerably lower slag basicity was used experimentally, so that somewhat higher sulphur contents had to be expected in the steel.

TABLE XI

Data on heat with additional smelting of ore fines with coke fines, heat 52597, 23·1%Fe gain from ore

Pig iron and scrap, kg	Proportion of pig iron, %	Ore, kg	Fe in ore, kg	Fe in ore, %	FeMn, kg	Total melt charged, kg	Coke fines, kg	Lime charged, kg	Lime later added, kg	Lime total, kg
30 800	49·6	10 500	7 130	23·1	230	38 160	1 900	1 200	200	1 400

Melting time: Charging and waiting, min	Melting time: Switch-on to 1st sample, min	Melting time: 1st sample to tap, min	Melting time: Tap to tap, min	Output and energy consumption: Switch-on to 1st sample t_E/h	Switch-on to 1st sample kWh/t_E	Tap to tap t_R/h	Tap to tap kWh/t_R
25	80	55	160	28·5	572	13·1	725

Pig-iron analysis, % C	Si	Mn	P	S	Steel composition, % C	Si	Mn	P	S
3·50	0·66	0·71	0·125	0·028	0·11	...	0·42	0·013	0·034

t_E = tons charged t_R = tons of molten steel

Nitrogen

Figure 12 shows the frequency distribution curve for the nitrogen contents obtained in the heats cast without killing. In about 70% of the heats, values of 0·004%N or less were obtained. Tests carried out later have shown that values of 0·002–0·003%N can be maintained for unkilled mild steels, and 0·004%N for killed steels.

EXPERIMENTS ON DIRECT STEELMAKING BY ADDITIONAL SMELTING OF ORE FINES WITH COKE FINES

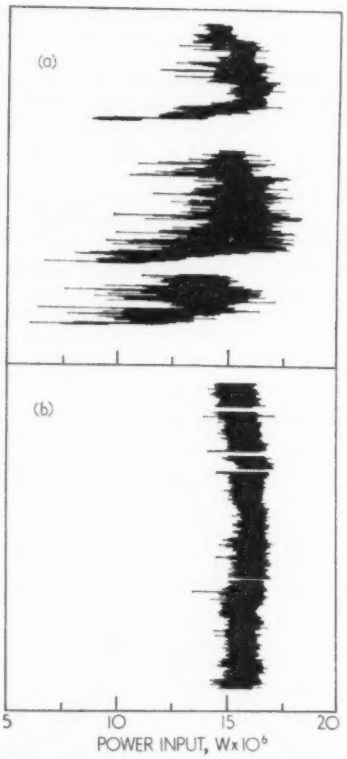
From the point of view of material costs, the gain in iron from the ore can have considerable economic importance. The iron in the ore is converted directly into steel ready to pour. Durrer[21] pointed out years ago that the pig iron plus ore process is the only one used on a truly industrial scale in which iron in the ore is converted in one operation to finished steel. It is only of secondary importance that this direct steelmaking is a side-issue and not the main aim of the process. Durrer[22] called this method of smelting 'smelting with liquid carbon' and he expressed the hope that one day it would become possible to develop a process of this type on a large industrial scale.

Following Durrer's line of thought, further tests were carried out in which more ore was added to the charge than required to refine the pig iron, and the extra ore reduced using additional solid carbon, e.g. coke fines, in the arc furnace.

In tests in the 12-ton and 40-ton furnaces, it was possible in this way to obtain an iron gain in the form of finished steel, amounting to more than one-third of the original metallic charge. Thus the molten-steel yield in terms of pig iron and scrap charged could be raised to more than 130%.

As an example of the economic possibilities of such a technique, data are given on a heat made in the 40-ton furnace. Table X shows the material balance for a heat in which additional iron to the amount of 23·1% of the weight of metal (pig iron and scrap) charged was obtained from ore and converted directly to steel. The yield in terms of the total metal content of the charge was 91·4%; it can thus be assumed that practically all the ore had been reduced and only the natural losses have occurred.

Table XI gives the operational data on this heat. In spite of the relatively extensive reduction required,



(*a*) 100% scrap (*b*) 50% pig iron plus additional reduction

Fig. 13—Input records for the 40-ton arc furnace with 100% scrap charge and with charge containing 50% liquid pig iron plus extra ore for reduction

the entire melting time from tap to tap was only 160 min. In comparison with the 100% scrap technique, roughly the same hourly output was attained despite the extensive reduction, but the energy consumption was increased by about 15–20%.

Since in this type of heat three processes, namely scrap melting, pig iron refining, and ore reduction by the additional solid carbon charged, are taking place side by side, it is difficult to find the true energy consumption for these three heat-consuming processes. An estimate of the heat consumed in melting the scrap and in refining the pig iron, on the basis of known consumption figures, suggests that one can reckon on requiring less than 2 000 kWh/ton for the energy to convert the ore directly to steel; in other words, less energy is needed than in the production of pig iron in the electric smelting furnace.

Finally, Fig. 13 reproduces input records for the 40-ton arc furnace, comparing the use of additional reduction with operation of the furnace with 100% scrap. With a charge consisting entirely of scrap, the frequent arc extinction leads to pronounced variations in input and to undesirable reactions back to the supply network. Both when liquid pig iron is charged and with additional reduction, as in the present example, the energy input is very steady and the furnace operates completely quietly.

SUMMARY AND CONCLUSIONS

Full-scale tests have been carried out in 12-ton and 40-ton arc furnaces in which the charges contained large proportions of liquid pig iron and ore was used as refining agent. The principle of the technique has been discussed and the progress of melting described and illustrated. Tests have shown that the refining reaction can be controlled despite the high refining rate.

Under continuous production conditions, both low-phosphorus and high-phosphorus qualities of pig iron have been used in the charge. In both cases a considerable increase in the hourly output together with a reduction in energy consumption have been recorded. In the 40-ton arc furnace it was possible to reach hourly outputs of up to about 15 tons/h with charges containing about 50% liquid high-phosphorus pig iron, and exceeding 18 tons/h with low-phosphorus, corresponding to an increase in output of 30% and 60% respectively, as against normal operation of the furnaces with 100% scrap charges. The energy consumption for the majority of heats was less than 500 kWh/ton of liquid steel.

Rich ore fines were particularly well suited as refining ores. With about 50% pig iron in the charge, one could expect a gain of about 8–10% of the charge weight from the ore. The metallic yield, referred to the metallic charge of pig iron and scrap, thus rose to more than 100%. The life of the furnace refractories was roughly as good as with 100% scrap charges. Durability figures of 137–163 heats were obtained for the walls and over 100 heats for the roof. The electrode consumption was about 5 kg/ton. High-phosphorus pig iron could be dephosphorized to low levels without notably extending the refining time. The P_2O_5 contents of better than 15% reached in the slag suggest that it can be used as a fertilizer.

Finally, it is shown in one example that the proportion of steel obtained directly from ore can be considerably increased by the additional reduction of ore fines with coke fines. Within the limits of the tests so far carried out, up to one-third of the weight of steel can be obtained directly from ore. The majority of tests were carried out with about 50% pig iron in the charge. When the pig-iron content was raised to about 70% roughly the same results were obtained.

The problem which originally formed the basis of this work, namely the economic conversion of high-phosphorus pig iron to steel in the arc furnace, can be regarded as solved, at least as far as conditions in Switzerland are concerned. With the increasing expansion of electric steelmaking, the problem of refining pig iron in the arc furnace has recently gained steadily in importance in other countries also. The present results will therefore be of wider interest than to the Swiss industry alone. If the authors' views are correct, arc furnaces will gain in competitive importance by the possibility of handling pig iron to the same extent as in O H furnaces. Thus it seems possible that in the not-too-distant future the electric steel process and the newly developed oxygen-blowing process will be the most important methods of steelmaking.

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An early medieval iron-smelting site in Weardale

By R. F. Tylecote

SYNOPSIS

The excavation yielded two primitive bowl hearths and a furnace of a more advanced type, all of which had been used for making wrought iron by the direct method. It is concluded that all three were blown with a forced draught provided by hand or foot bellows. The charge consisted of local bog-iron ore and mainly oak charcoal. The products found were slags and cinders; since the latter were only found in the hearths it was concluded that they were resmelted. 1560

MOST METALLURGISTS are by now used to examining various ferrous and non-ferrous specimens for their archaeological colleagues, and at the end of many archaeological reports one finds the results of their labours. But, whereas specimens of slag and metal are readily forthcoming, discoveries of furnaces are not so frequent, and it was the dearth of evidence relating to these that prompted the author to try and find a site which would throw some light on primitive techniques used for iron smelting in the north of England.

The account rolls of a Bishop of Durham give some information on the conduct of a smelting site in Weardale in 1409, but it has not yet proved possible to identify the site. The information is mainly of an economic character and, while there are some hints about the technique used, they do little more than whet the appetite of the reader.

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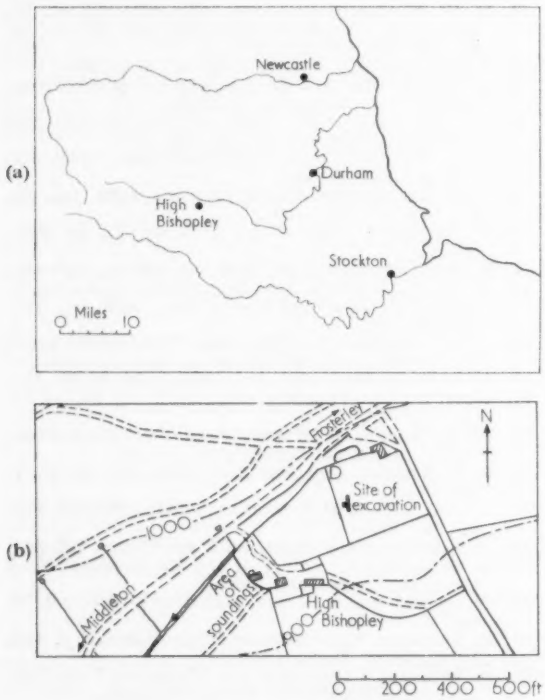
The site which forms the subject of this excavation was found by the presence of slag in a farm road and fields. This was easily recognized as primitive slag by being dark and heavy. During the deep ploughing of certain fields it had been noticed that some areas contained more slag than others. These were pointed out by the tenant, and preliminary soundings produced slag, charcoal, and ore. The presence of these together showed that the existence of a primitive smelting site was a very strong probability.

THE SITE

The excavation was made near the farm of High Bishopley which lies one mile south-west of Frosterley



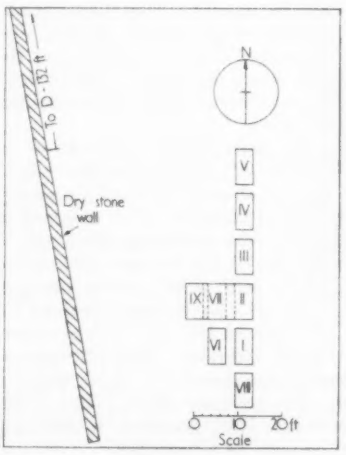


Fig. 1 — Position and plan of excavation trench system

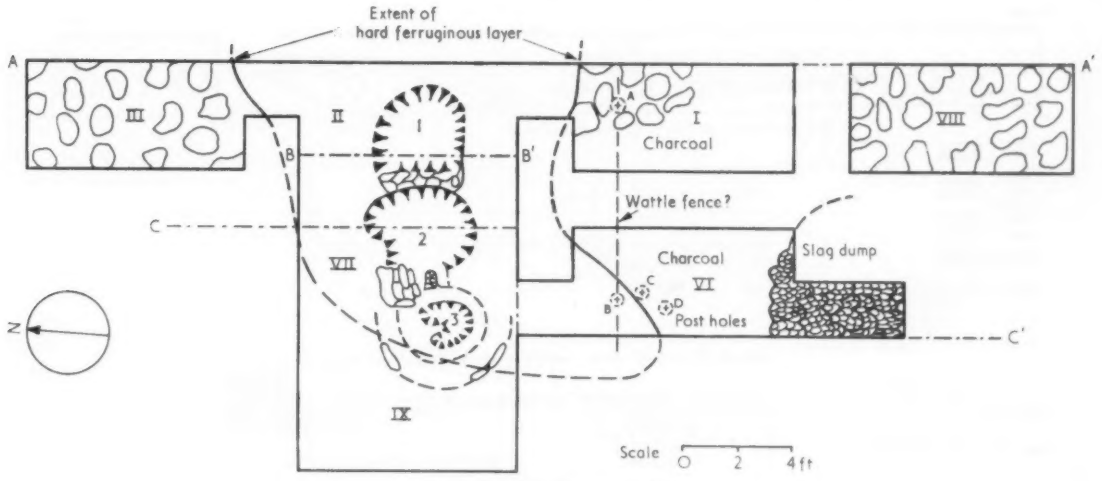


Fig. 2—Plan of excavation

in Weardale, Co. Durham. The reference to the 1-in. O.S. is sheet 84, 012355, and the farm appears on sheet NZ 03 NW 1953 on the 6-in. scale. The site was on sloping ground at an altitude of 950 ft, 200 ft above the Bollihope burn.

The iron-working area appears on the ground as a slight easing of the gradient with some small rises here and there. It follows the 950-ft contour for about 300 yards and, before excavating, a number of soundings were made in May, 1957, at both ends of the area. In both sets of soundings a large amount of slag was found, together with charcoal and small pieces of ore. This confirmed the probability that smelting had been carried out here at some time, probably in both the fields sounded (Fig. 1*b*).

In September, 1957, it was decided to excavate in the area of the more easterly set of soundings, where there appeared to be signs of a levelling in the slope of the hillside. A line of 8 ft × 4 ft trenches was laid out, going up the hill, the aim being to cut through the partly levelled region. The actual gradient in this region was 1 in 10, the general gradient being 1 in 4.

The second trench going uphill from the bottom revealed part of a hearth, and the area to the west of this was then excavated, using a grid of 8 ft × 4 ft rectangles with 2-ft baulks between. Some of the baulks were removed in the later stages after sections had been drawn.

THE EXCAVATIONS

A plan of the trench system used is shown in Fig. 1*c*, the trenches being numbered in the order in which they were dug. The whole area was found to be covered with a layer of topsoil which, including the turf, varied from about 4 in. to 8 in. The fields had been ploughed in the last few years, but it is unlikely, considering the height of the furnace remains, that the effective depth of the ploughing exceeded about 4 in. The rest of the topsoil layer was therefore mainly silt washed down from higher up the hillside, which had obviously had a levelling effect on the remains after the iron-smelting operations ceased.

Trench VIII: In this, the lowest trench, a large number of stones were found below the topsoil, some bearing traces of the indigo-coloured bog-iron ore of the locality, and here there were also some medieval potsherds. The subsoil was at a depth of about 1ft; it was light-coloured and sandy, and contained some small pieces of sandstone.

Trench I also contained a fair amount of stone, but in some parts which were free from stone, and in some cases between the stones, there was a considerable quantity of charcoal. Some of this was in large pieces of 1–2 in. and some was merely dust, but the actual charcoal content of many of the samples taken exceeded 70%. On removing the stones and charcoal, subsoil was met at a depth of 11–15 in., and in this was found a hollow about 5 in. dia., filled with charcoal, 2 in. deep. The charcoal filling of the hollow appeared not to have been formed *in situ*, but to have fallen in upon withdrawal of a post.

Trench II: In the centre were found some large pieces of slag, and below this, covering the whole trench at a level varying from 6 in. to 11 in., a hard ferruginous layer was encountered (Fig. 2). This layer varied in thickness from 2 in. to 5 in., and seemed to represent a working floor. On its removal there was revealed a semi-circular hearth filled with cinder of similar hardness, colour, and composition to the layer, its western third disappearing under the baulk. When encountered, the diameter of this hearth was about 4 ft; it later became clear that the hearth had not been covered by the hard layer, but that the top surface of the hearth was level with the top of the hard layer and indistinguishable from it.

Trenches III, IV, and V were filled with stones bearing traces of bog-iron ore as in Trench VIII. It appeared that the contents of all these trenches were the result of stripping the bog-iron ore, which probably covered the hillside to a depth of 3 or 4 in., removing included stones from the ore, and dumping

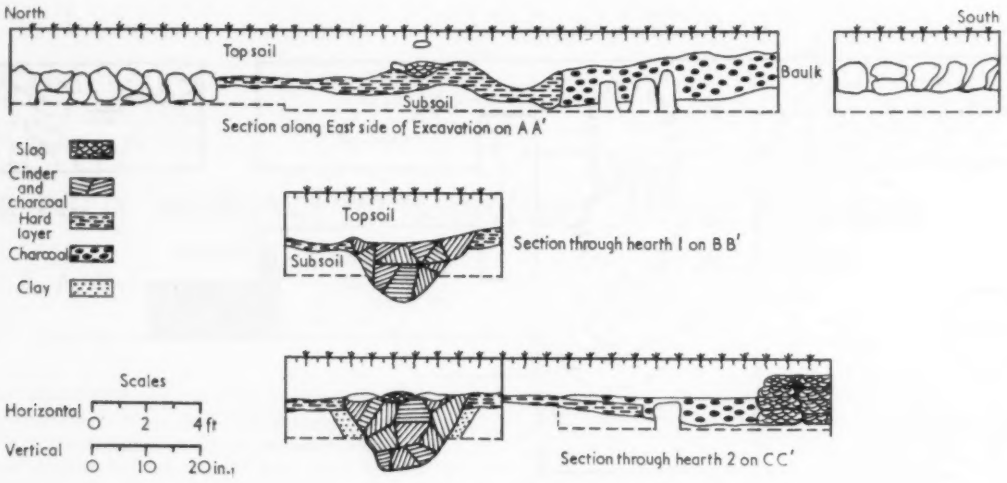


Fig. 3—Sections of excavation

them back in the stripped areas. A few 13th-century potsherds were found in these trenches, as in Trench I, at subsoil level. Most of them lay amongst the charcoal of Trench I, and they may be taken to date the origin of the site to the 13th century.

Trenches I and II were developed in a westerly direction, by laying out further trenches (VI, VII, IX), since it was clear that this area would be the most profitable, though it is also extremely probable that other hearths lie to the east of Trench II. The results of this westward extension are described below.

Trench VII revealed more of the hard layer and a second hearth similar in form to that in Trench II, with its eastern side disappearing under the baulk between Trenches II and VII. This baulk was later removed, revealing that the east side of the second hearth overlay the west side of the first. On the west side of Trench VII the structure of a third hearth was visible, standing to a height of 6 in. below the surface. This hearth was obviously quite different in structure from the other two. The diameter was much smaller, and the hard layer did not surround it, but appeared to thin out and disappear to the east of it. It resembled the other two, in being filled with cinder so hard that it had to be removed with a hammer and chisel before the internal shape of the hearth could be studied. The hearth was formed from a hard-baked lining of clay, stones, and slag, very much harder than the red clay lining surrounding the second hearth. Furthermore, evidence of tuyeres and slag tapping positions also came to light, the slag being visible *in situ* in Fig. 6. Trench VII was extended by laying out one further trench (IX) to the west.

Trench IX was temporarily separated from VII by a baulk 1 ft wide which was removed when sections had been drawn. Trench IX and the area under the intervening baulk showed the full extent of the third hearth. This hearth could more correctly be called a furnace, since it was quite clearly a taller structure than hearths 1 and 2.

The west half of Trench IX was completely barren except for signs of ore stripping, and it would appear that the close succession of hearths, probably beginning to the east of the excavated area, ceases with the third structure.

Trench VI, lying to the south of the hearth area, showed that the hard ferruginous layer extended to the south and finished up against a layer containing a few large stones and a high proportion of charcoal and charcoal dust. This trench had in fact the same stratification as Trench I, and also produced a group of three postholes containing charcoal, about 5 in. dia. and 4–6 in. deep, similar to the posthole in Trench I.

The south end of this trench contained a large amount of broken slag, and an extension in a southerly direction down the slope produced slag from a depth of 3 in., to the subsoil at 12 in. It is clear that in this area there had been a slag heap. It would appear that the area immediately to the north of this, comprising the greater part of Trenches I and VI, must have been used for a charcoal dump after stripping of the ore. The charcoal appears to have been retained and prevented from spreading over the working area by some sort of fence supported by posts along the line of postholes *A* and *B*. Postholes *C* and *D* are probably due to replacements. Section *AA'* in Fig. 3 shows a vertical joint between the hard layer and the charcoal, and suggests that the two layers were built up simultaneously over a period of time.

THE HARD FERRUGINOUS LAYER

The larger part of the hearth area was covered with a hard ferruginous layer varying in thickness from 1 in. to 4 in.; its hardness was such that it needed violent picking to penetrate it and remove it. The actual extent is shown in the plan in Fig. 2; it covers an area of about 8 ft dia., from hearths 1 and 2, the southern limit being the charcoal heap with its probable retaining fence on the line of the postholes. It dies out at a thickness of about 2 in. on the northern side, where it comes into contact with the stones resulting from the stripping of the ore.

TABLE I

Composition of ferruginous materials from High Bishopley, wt-%

	Slag from slag heap	Hard ferruginous layer	Cinder from hearth 1	Cinder from hearth 2	Slag from hearth 3	Ore	
						Natural	Calcined
	A	B	C	D	E	F	G
FeO	31·0	...	11·2	8·6	17·0	...	...
Fe_2O_3	26·4	49·8	40·3	45·6	22·1	39·2	50·0
SiO_2	20·3	25·6	22·7	16·2	48·9	21·5	27·4
Al_2O_3	2·4	2·5	3·4	1·6	3·7	2·1	2·7
MnO_2	13·1	6·0	8·8	11·3	3·5	12·1	15·5
CaO	2·7	1·9	2·6	2·7	1·3	1·2	1·5
MgO	1·9	<0·1 i.a.	<0·1 i.a.	<0·1 i.a.	<0·1 i.a.	1·3	1·7
Loss on ignition	n.d.	8·0	5·3	7·2	1·6	7·1	...
H_2O	n.d.	5·6	6·0	5·4	1·2	14·7	...
Total	97·8	99·4	100·3	98·6	99·3	99·2	98·8

i.a. = if any n.d. = not determined

Its actual course across the trench in the area of hearth 3 is somewhat obscure, since it was confused with the debris from hearth 3. Its course across Trench VII is inferred from its appearance in the sides of the baulks. The fact that hearth 3 cuts across the line of the hard layer indicates that it has nothing to do with this particular hearth; also its western edge is only about 1 in. thick.

Therefore, it was concluded that this layer must be connected with the operation of hearths 1 and 2 and any hearths lying to the east of these, but so far unexcavated. Its analysis is given in column *B* of Table I. It is a hard, laminated material, consisting of, in the main, yellow-brown granular material, but with some streaks of indigo material strongly resembling the original bog ore, about 1 in. apart. In some places it contains fine charcoal dust and larger pieces of charcoal.

The fact that it contains charcoal at all shows conclusively that it is not a water-deposited layer such as the ore itself, or a 'hard pan'. It appears to consist of the finer particles of the ore and charcoal dust. It is probably the fine dust that has been blown off the smelting fires in hearths 1 and 2, and compacted into a working floor. It probably contains the finer components of the ore which have never actually reached the hearths. When allowance has been made for the higher moisture content of the ore, the analysis of the hard layer and the ore are very similar except for the manganese content.

Its disposition, therefore, gives a clue to the succession of the hearths and the history of the site. It seems that as far as the excavated area of the site is concerned, hearths 1 and 2 were in use before 3. Hearth 3 was partly cut through ground that had been covered with a 1-in. layer formed during the life of 1 and 2. Furthermore, either hearth 3 was of a different type and did not cause as much spreading of the charge due to wind-blowing as 1 and 2, or it was in use for a very much shorter time.

The fact that the prevailing wind is westerly would, of course, tend to keep the area to the west of hearth 3 free from dust from the charge, but it is difficult to believe that there would be absolutely no hard layer if hearth 3 had been worked in the same way as the others.

No potsherds were found beneath this layer, which is unfortunate, since it is a sealing layer and therefore any datable material found below it would provide a most reliable date for the earliest use of the site.

THE HEARTHS

During the excavation three hearths were located and examined, and a general view of the hearth area is shown in Fig. 5. Hearths 1 and 2 were of approximately the same type, and their remains formed 'bowls' of about 3 ft 6 in. dia. by 13–14 in. deep. Hearths 1 and 2 were filled with cinder level with the hard ferruginous layer. This layer was very difficult to distinguish from the cinder when damp, although when dried the cinder was found to be a good deal darker. In Fig. 2, hearth 1 is shown in its original shape, approximately circular. At first, during excavation, it appeared to be semi-circular, the upper level of its west half having been filled in with stone, clay, and slag, but later it became apparent that hearth 2 had been constructed by partially filling in hearth 1 to make a lining for the latter. It seems that the slag from hearth 1 was tapped towards what was later to become hearth 2. This would be done by cutting a short V-shaped channel and allowing the slag to run out at intervals during the smelting operation. As may be seen in the section shown in Fig. 4, this channel, on a level slightly below the bottom of hearth 1, has not been completely obscured by the clay and stone filling forming the lining of hearth 2. A piece of charred hazel nut was found in the filling of hearth 1.

Hearth 2 was probably made because hearth 1 became filled with cinder, and it was easier to construct a new hearth rather than excavate the old. If hearth 1 was used after the construction of 2, it

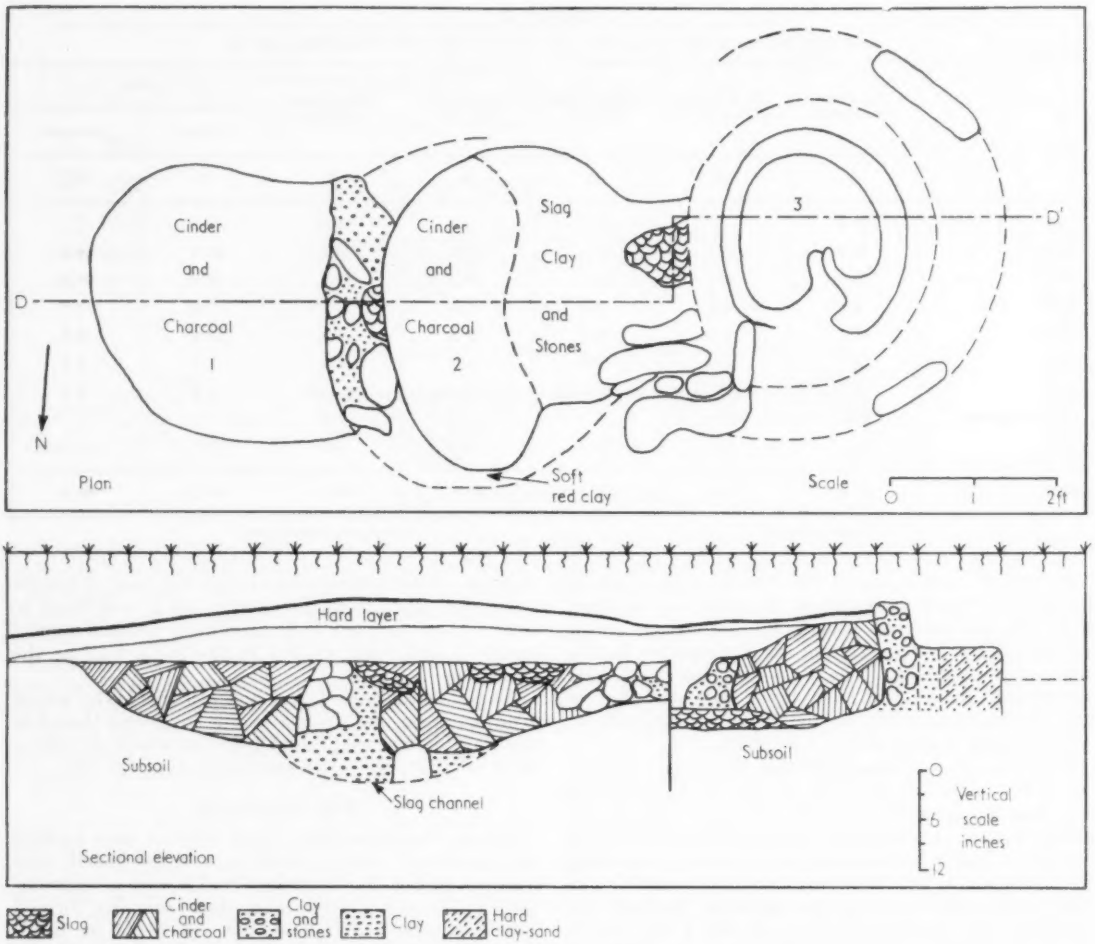


Fig. 4—Plan and section of hearth area

would be as a semi-circular type with a back wall, as has been found in an excavation at Huckoe in Northumberland.[8] This is, however, considered to be extremely unlikely.

Hearth 2 was similar in shape and capacity to 1, but had a rather steep east side formed by the lining wall. It would be tapped towards hearth 3 into a cutting which was later to be used for tapping this hearth also. The north side and most of the south side of this hearth was lined with a 4-in. thick layer of soft clay, which was burnt red. The contents were mostly cinder, harder and darker than that of hearth 1 but very similar in analysis. Incorporated in the lining wall was a large piece of slag which had fused on to the cinder in the hearth.

Hearth 3 was completely different from the other two. First, the base of the hearth was flatter, and secondly the diameter at a height of 15 in. was several inches less than at the bottom. Furthermore, the hearth area is smaller than the others, measuring about 20 in. in diameter. Also it is kidney-shaped, the lobes being filled with cinder which was rather harder than that filling the rest of the hearth.

It seems that the lobes were formed by the presence of a tuyere which was set some 7 in. from the bottom and pointed downwards at a slight angle. No sign

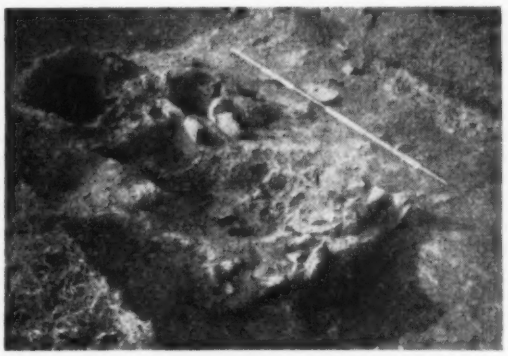


Fig. 5—View of hearth area looking N.W.

of a tuyere was found, but its supporting ledge, consisting of hard clay on cinder, is clearly shown in plan in Fig. 4 and in Fig. 6.

The furnace, as this should more correctly be called, was tapped to one side into the channel formed for tapping hearth 2. Slag was found *in situ* in this channel (*see* Fig. 6) and was continuous with the slag found within hearth 3 itself. The analysis of the latter is given in Table I (column *E*).

The walls of the furnace were composed of a mixture of clayey sand, stone, and slag. The first 4 in. of their thickness were baked quite hard, and withstood the damaging effect of the hammer and cold chisel that were used to remove the cinder within the furnace. The outer layers of the walls tended to merge with the surrounding subsoil, and at subsoil level the main indication of their extent was the presence of a few stones at a radius of 2 ft 6 in. from the centre of the furnace. The sandy clay within the radius was somewhat harder than that outside.

To provide access to the tuyere, the thick walls of the furnace were supported by a block consisting of stones, clay, and slag on the east side, as shown in the plan in Fig. 4. It might have been expected that there would be a similar structure on the west side to provide access to the hearth, but no traces were observed. On the east side of the furnace at the level of the bottom the wall was cut away to permit the tapping of slag as shown (Fig. 4).

From these remains it is possible to form some idea of the original furnace. In many ways it would resemble that shown by Coghlan,[1] which was found near Engsbachtal in the Siegerland, and reported by Weiershausen in 1939.[2] The principal difference is that the furnace found in this excavation in County Durham was blown with a forced draught (it faces north and uphill) and not by natural draught. Furthermore, the manner of tapping slag is clear, whereas at Engsbachtal it is doubtful whether slag was tapped at all. The bloom would probably have been removed through the tuyere passage after removal of bellows and tuyere. It would have needed very long tools, but there is documentary evidence for such tackle in Wearsdale in the 15th century.[3] After removal of the bloom, the damage would be made good with fresh clay-sand and the tuyere re-inserted.

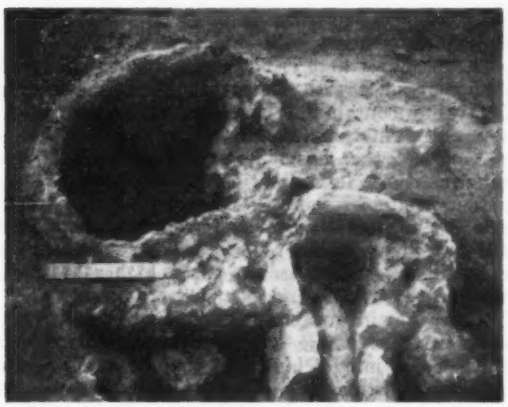


Fig. 6—Hearth 3, showing tapped slag

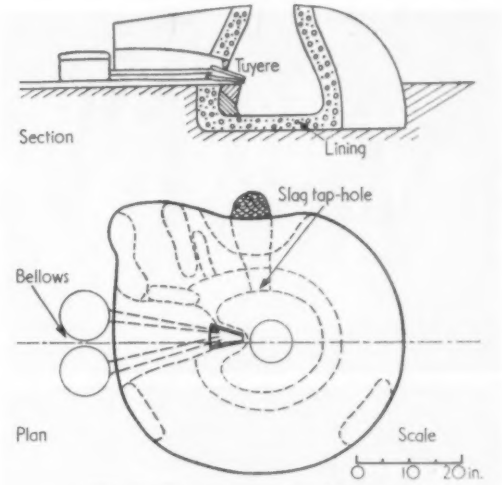


Fig. 7—Reconstruction of furnace

Charging would be carried out with a mixture of ore and charcoal through the restricted hole in the top. This would be very much more efficient than in the case of the bowl furnaces, and there would be less loss of heat and the finer constituents of the charge due to wind.

A reconstruction of this furnace is shown in Fig. 7.

THE ORE

There is little doubt that the ore smelted on this site was the local bog-iron ore. Although there is now no ore in the immediate vicinity, the author has seen deposits at Boltshaw and East Biggins, both in the dale. The ore is an indigo colour, indicative of high manganese content, and occurs in thicknesses of 3–4 in. and at depths of about 8 in. Deep ploughing tends to dig it up in patches, but sometimes the plough overrides it, and at others it tends to dig into it and loosen it. It is mainly a product of arctic and sub-arctic conditions and is generally deposited on the bottom of lakes. This is not always the case, and the deposits in Weardale have never been lake deposits. They seem to have been formed when iron-bearing surface water met waterlogged organic areas providing suitable conditions for precipitation.

The ore contains large and small pieces of yellow or orange sandstone. The smaller pieces are removed by breaking up the ore, and these are the pieces found in the excavation, bearing traces of attached ore. The analysis of the ore (Table I, column *F*) shows the presence of organic matter (as ignition loss) which presumably comes from the roots of plants. The ore is highly porous and this in itself makes it an ideal material for the primitive smelting process.

There is no evidence for roasting; since the main purpose of the roasting process is to open up the ore and make it more permeable to the reducing gases there would be no need for it in this case.

When the water and some of the organic constituents were driven off, which would happen in the

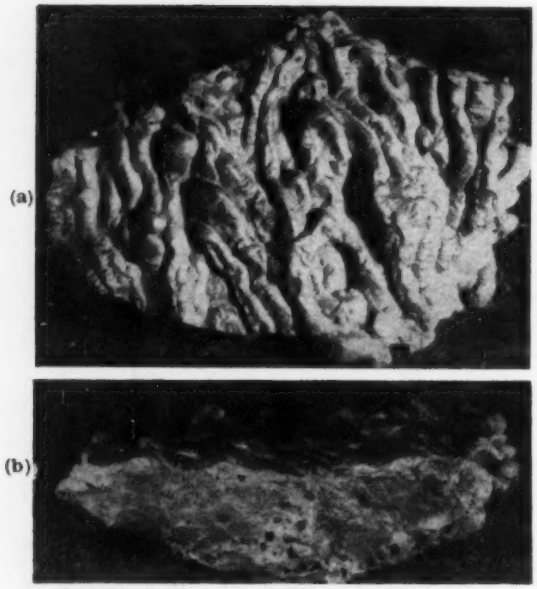


Fig. 8—Slag: (*a*) top surface, (*b*) section × ½

early stages of hearth smelting, the ore would have the relatively high (Fe + Mn oxides) content of 65% and be classed as a high-grade ore.

THE SLAG

Large quantities of slag were found over a radius of 200 yd round the area excavated. Pieces of slag could be picked up from the road metal of the farm roads. These pieces and those found in the slag heap of the excavation all had the same characteristics. The surface appearance is shown in Fig. 8*a*; the slag has been run off in a semi-fluid state, with the top surface exposed so that the rivulets of hot semi-molten slag could solidify with a smooth shiny surface. A cross-section of the slag is shown in Fig. 8*b*, in which it is clear that the porosity is not great. The bottom surface of all pieces of slag is rough, and the large pieces have a V-shaped bottom, which is strongly suggestive of their having been tapped into a V-shaped channel made with sloping cuts of a spade. One piece which showed this very clearly was 15 in. long × 10 in. wide and weighed 29 lb.

The specific gravity of the dense pieces of slag shown in Figs. 8*a* and *b* was 3·72, typical of a high iron-containing slag. It was of interest to determine the free-running temperature of the slag, as it would give some indication of furnace temperature. In this connection it should be noted that slags are like glasses, and therefore have no sharply defined melting point, but get less viscous as their temperature is increased until finally they can be run off in a more or less fluid condition. Determinations of the free-running temperature of this slag were therefore made in air and in a reducing atmosphere, since it is recongized that the atmosphere has a considerable effect on this. It was found to begin to run at 1 170° C, and was only really fluid at 1 200° C in hydrogen. In air, the free-running temperature was 1 250° C.

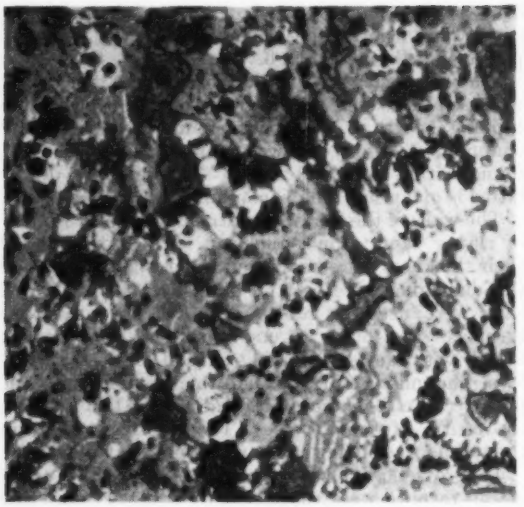


Fig. 9—Microstructure of slag *A*, showing dendrites of magnetite in a fayalite-type melt × 400

The chemical composition of the slags is given in columns *A* and *E* of Table I. Slag *A* is a typical smelting slag and represents the bulk of the slags from the site, and consists of dendrites of magnetite in a fayalite-type melt (Fig. 9). With a total (Fe + Mn oxides) content of 70·5%, it compares well with other slags from primitive smelting sites, such as those found by Gilles,[4] and samples brought to the author from Wark-on-Tyne (66·7% Fe + Mn oxides) and Great Casterton (73·7% Fe + Mn oxides). In all cases the silica content was of the order of 20%.

Considering the high manganese oxide content of the local bog-iron ore, and the fact that, in this process, all the manganese in the ore goes into the slag, the high MnO_2 content of the slag is not surprising.

The slag from the bottom of hearth 3, which was continuous with that being tapped and is visible in Fig. 6, was different in many ways. First it was much more porous, the rivulets being hollow and more like bubbles, and it was much lighter in colour. The analysis is given in column *E* of Table I. It has a considerably higher silica content and a lower (Fe + Mn oxides) content than the others. The microstructure shows that it consists of a large amount of angular silica with a cementing phase consisting of fayalite containing magnetite and some silica. It would seem therefore, that this slag is either a smelting slag that has some of the siliceous furnace lining fused into it, so diluting the (Fe + Mn oxides) contents, but increasing the silica and alumina contents, or else is a smithing slag in which sand has been used as a flux. Gilles[4] reports that ' stryng hearth ' or smithing-hearth slags are often higher in silica, owing to the use of sand as a flux. It would seem, however, that in working up the bloom in the stryng hearth a considerable loss of iron as scale would result, maintaining a high iron content in the waste material. Furthermore, there would then be no necessity to tap such a slag. Consequently the author prefers the former explanation. The free-running

temperature of this slag would be appreciably higher than the others because of the higher silica content, and would tend to suggest the use of a more advanced, and presumably later, technique.

THE CINDER

The term 'cinder' in this report applies to the partially reduced ore which tends to line the primitive hearths after smelting. It is usually highly porous and heterogeneous, and contains pieces of charcoal or other fuel, such as raw wood and coal when it has been used. Physically, it is quite different from the slag, but after making allowance for the unburnt fuel component, it is chemically very similar. It contains some partially reduced iron oxide from the ore, as FeO or Fe_3O_4 and a cementing slag phase which is mainly fayalite with some other oxides in solution.

As found, the cinders tend to vary in colour from brown to black according to the condition of the ground, in particular the degree of hydration of the ferrous components. Analyses of cinders from hearths 1 and 2 are given in Table I (columns *C* and *D*). The cinder from hearth 2 was a much darker, harder, and denser material than that from hearth 1 and contained far more of the slag phase. It also appeared to have its carbonaceous phase in more finely distributed form, which also contributes to its darker colour. The loss on ignition, which is mainly due to the burning of the carbon, is higher for the cinder from hearth 2 than that from hearth 1. The higher moisture contents would be expected for such porous material.

All the cinders found in this excavation were found *in situ* in the three hearths. During the excavation of a Roman villa at Great Weldon in Northamptonshire, some large pieces, weighing as much as 80 lb, were found built into the foundations of a barn of Roman date.[6] It would seem that normally the cinders, being porous and relatively soft, are broken up and resmelted with a proportion of new ore and charcoal. This would account for the absence of cinder in the slag-heap at High Bishopley. Presumably at Great Weldon the pieces were too big or too hard, or represented the contents of disused hearths. Slag, on the other hand, being so much denser and harder, would not be suitable for resmelting in these primitive hearths.

After smelting, not all the cinder from the previous smelt would be removed. This would be an extremely difficult operation at any time and unnecessary, as the remaining cinder forms a lining for the hearth. During excavation the cinder had to be chipped out with a hammer and chisel to determine the actual shape of the hearth. It certainly would not be much easier for the primitive smelter. Probably sufficient cinder would be extracted adhering to the bloom to make sufficient room for a fresh charge. The adhering cinder would protect the bloom from oxidation, and would be removed during its subsequent working.

Examination of Table I shows that the ratio of silica to iron oxides is higher in the ore than in the slag. It would seem that the ore actually used to produce such a slag had on the average a lower silica/iron-oxide ratio, or else a considerable proportion of cinder was used in the charge, with a composition such as that shown under column *D*. When this is calcined (roasted) the proportion of iron oxides, silica, and manganese oxide become very similar to that shown in the slag under column *A*.

TABLE II

Possible materials balance

	Charge			Product	
	Calcined cinder (hearth 2) 1·0 lb	Ash 0·09 lb	Total	Iron	Slag
FeO, Fe_2O_3	0·61	...	0·61		0·58
MnO_2	0·13	...	0·13		0·13
SiO_2	0·18	0·02	0·20		0·20
Basic oxides	0·05	0·04	0·09		0·08
Na, K, P_2O_5	0·03	0·02 0·01	0·04 0·02		0·04 0·03
Iron	...	...	...	0·026	...
Total	1·00	0·09	1·09	0·026	1·06

Assumptions:
(1) Charge; dry cinder from hearth 2
(2) Yield of iron = 7½% of iron in ore
(3) Charcoal consumption = 16 lb/lb of iron produced
(4) Charcoal ash content = 20%

The actual iron yield as a percentage of the iron present in the ore is often as low as 7½%, according to Schubert,[5] although a figure as high as 20% has been obtained in recent experimental work on the primitive process.[7]

Assuming an iron yield of 7½% and a charcoal ash content of 20%, made up of 50% basic oxides, 20% alkali, 10% P_2O_5, and 20% SiO_2, as found by Gilles,[4] the materials balance, shown in Table II, can be obtained.

This is based on a charge of calcined cinder from hearth 2. If some ore is substituted for a small part of the cinder, the difference will be negligible, but if larger amounts of ore were used one must conclude that this ore was of a better grade than that found and analysed.

THE CHARCOAL

Sections of the larger pieces of charcoal were kindly made by Dr W. A. Clarke, who reports that more than 90% of them consist of oak, the remainder being hazel and beech. The oaks were slow-growing, and it is therefore possible that they are similar to the small stunted oaks which may be found in the area today.

Since the charcoal was heavily permeated with deposited mineral matter, analysis of the ash content would be inaccurate.

According to Lapsley,[3] in 1408 Bishop Langley forbade the use of oak for charcoal for his bloomery at Byrkeknott nearby. It would appear, therefore, that either High Bishopley was not under the Bishop's jurisdiction, or that when the site was in use, there was a plentiful supply of small oak for charcoal and no ban existed on its use.

SUMMARY AND CONCLUSIONS

The remains excavated are those of an iron-smelting site datable on pottery evidence to the 13th century A.D. Three furnaces were found, two of the most primitive bowl-hearth type with provision for the tapping of slag, and a third of a more advanced type, which is similar to the domed furnace found in the Siegerland except that it was blown with a forced draught. All the furnaces would have been blown with hand or foot bellows, since their height above the burn would have made it impossible to employ water-power. No traces of the bellows, or of tuyeres, were found, although the later furnace showed that the tuyere was placed about 7 in. above the bottom, pointing downwards at a slight angle.

The positions of the charcoal and slag heaps were identified, in addition to that of a hard ferruginous working floor.

Some of the slag from the more advanced furnace was found *in situ*, showing the point of tapping. In analysis it was higher in silica and lower in iron than the slag from the two more primitive hearths and indicates the use of a higher temperature. The free-running temperature of most of the slag found on the site would have been about 1 200° C, which would probably correspond to the maximum temperature of the bowl furnaces.

There was no indication as to whether either of the bowl furnaces was ever used as a 'stryng hearth' or forging hearth, although their contents show that ultimately they were used as smelting hearths.

ACKNOWLEDGMENTS

Thanks are due to the owner, Mr J. H. Pickering, and the tenant, Mr D. Skidmore, for permission to excavate; to Mr H. Laming of this department for analysing the slags, ores and cinders; to Mr E. J. Wynne for help in all aspects of the work; to Mr J. Newrick, who both located the site and helped in its excavation; to Mr J. P. Gillam for his examination of the pottery; to Dr D. Smith for the photography; to Dr W. A. Clarke for the examination of the charcoal; to the Durham University Excavation Committee and Mr Noel Shaw for the loan of equipment; and to the many others who assisted in the excavation.

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Heat transfer investigations and development of the automatic control of power input on the BISRA 10-cwt arc furnace

By J. Ravenscroft, B.Sc., A.M.I.E.E., A.R.T.C.S., and L. McGee

SYNOPSIS

This paper describes investigations carried out on a 10-cwt Heroult arc furnace to determine (*a*) the effects of furnace voltage and power input on melting time and electricity consumption during the melting period, and (*b*) the rate of heat transfer from the arcs to the molten charge during the refining period. A method is described for controlling power input by roof temperature and details of a programme controller for controlling the power input to the furnace for the complete melting cycle are also given.

During refining:

(i) refractory temperatures increased with furnace voltage

(ii) for a given furnace voltage, rate of bath temperature rise increased with electrode current

(iii) for a given power input, rate of bath temperature rise decreased with increase of furnace voltage.

During melting, reducing the high power after 25 min, instead of retaining the top voltage until melt-out, reduced the electricity consumption but increased melting time. 1692

ARC FURNACE roof temperature investigations on production furnaces have shown that high temperatures often occur at the end of melting and during the refining period of the steelmaking process, although at these times the molten-bath temperatures might be normal. The cause of high roof temperatures is, in general, due to the inefficient use of the electrical power input to the furnace; at the end of the melting period particularly, very high temperatures can occur if the high power is left on too long.

Paper SM/AC/198/58 of the Electric Process Sub-Committee of the Steel Practice Committee of the Steelmaking Division of the British Iron and Steel Research Association, received on 11th February, 1959. The views expressed are the authors', and are not necessarily endorsed by the Committee as a body.

The authors are at the Association's Sheffield laboratories.

Control of power input during the oxidizing and reducing periods of the furnace cycle requires a different technique than for the melting period. During melting the electrical losses are most important and since the arcs are shielded by the scrap, once the electrodes have bored down into the charge, the rate of heat transfer to the steel is high. Consequently, it should be an advantage to use as high a voltage as possible at this stage, since for a given power input the electrical losses decrease with increase of furnace voltage.

When the bath is molten the arcs are no longer shielded and the furnace refractories are exposed to direct radiation and convection from these very high energy sources. Since arc length is proportional to arc voltage, the problem during refining is to select the right voltage tap for the required power input and to balance thermal losses against electrical losses.

The BISRA 10-cwt arc furnace has been fully described elsewhere.* The present investigations have been made to try to determine the best voltage and current combinations to use during refining in order to maintain desired bath conditions, or to produce a given rate of bath temperature rise. A preliminary study of the mode of heat transfer during the melting period has also been made and the results obtained have been used to design a programme controller for the automatic control of power input to the furnace.

It is emphasized that the work described in this report was conducted on a small experimental unit and the results obtained would not be expected to apply directly to large production furnaces, but the general principles should still hold.

*W. H. GLAISHER, M. PRESTON, and J. RAVENSCROFT: *JISI*, 1956, vol. 183, pp. 22–41.

TABLE I

Effect of power input on bath and refractory temperatures during refining

Control setting		Open circuit volts	Mean electrode current, A	Mean power input, kW	Approximate arc power, kW	Bath temp. rise, °C/min	Refractory temp. rise, °C/min		
							Roof	Top of wall	Bottom of wall
V	A								
1	4		1 100	121	88	− 3	1	2	3
1	6	64	1 700	219	159	5	3	3	6
1	8		2 390	288	209	3	0	7	3
2	2		620	109	99	0	1	0	0
2	3		810	114	101	− 1	1	2	1
2	4		1 000	154	122	0	6	6	8
2	5	75	1 200	183	145	− 1	4	5	6
2	6		1 750	274	194	11	13	13	16
2	8		2 130	312	222	6	11	12	12
3	2		675	110	100	− 2	4	6	7
3	3		900	143	128	− 1	1	3	5
3	4	88	1 140	184	161	2	8	12	16
3	5		1 420	221	192	6	3	1	10
3	6		1 735	294	228	11	7	17	22
3	8		2 700	414	302	9	14	22	26
4	4		1 150	240	183	2	8	9	2
4	6	104	1 780	367	291	12	9	10	13
4	8		2 550	495	400	9	23	21	29
7	3	153	1 000	294	251	− 1	16	20	17
8	3		970	304	285	− 2	12	17	23
8	4	180	1 270	374	356	5	19	...	...
8	8		2 200	579	508	12	50	...	...

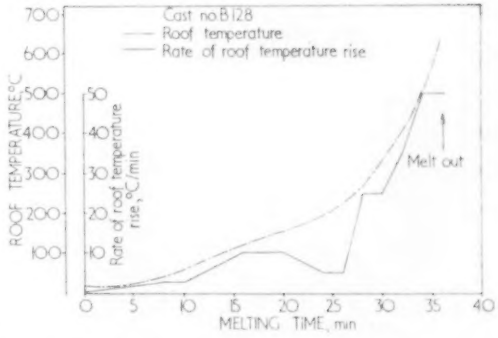

Fig. 1—Effect of power input on roof temperature, 180 V, 2 300 A

HEAT TRANSFER INVESTIGATIONS DURING REFINING

Several heats were made in the BISRA furnace for the purpose of heat transfer investigations and in each case the charge weight was 10 cwt and Pt/Rh–Pt thermocouples were inserted in the roof and the furnace walls so that refractory temperatures could be measured. The thermocouples were sheathed in closed-end recrystallized alumina tubes and, in addition, the roof thermocouple was protected by an outer sheath of silicon carbide. The outputs from the thermocouples were recorded on a potentiometric recorder.

Before any observations of heat transfer were taken the furnace refractories were allowed to reach a steady temperature by keeping the power input constant for a long period. The bath temperature corresponding to the steady state was also measured by immersion pyrometry.

When steady conditions were reached, changes of bath and refractory temperatures were noted for fixed power inputs on different voltage and current settings. The power input was determined by using the furnace integrating kWh meter to measure the number of units consumed during a fixed time interval. An assessment of arc power was made by measuring the the power at the electrode holders and the voltage drop along the electrodes for each current. After the results for a given power input had been obtained, the furnace temperatures were allowed to stabilize before a further investigation was made.

Results

A summary of all the results obtained is given in Table I, although it should be appreciated that owing to continually changing furnace conditions, such as roof life, wall life, etc., only a rough comparison can be made between results obtained on different casts.

From an examination of the results the general trends observed are that:

(i) rates of refractory temperature rise increase with furnace voltage

(ii) for a given furnace voltage, the rate of bath temperature rise increases with current, although there is an indication that maximum rate of heat transfer to the bath occurs for a current of the order of 1 700–1 800 A

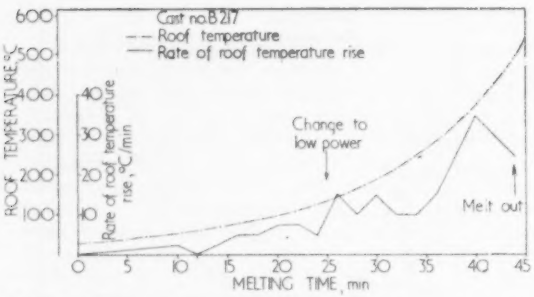

Fig. 2—Effect of power input on roof temperature, 180 V, 2 300 A and 88 V, 2 700 A

(iii) for a given power input, the rate of bath temperature rise decreases with increase of furnace voltage and there is a corresponding increase in the rate of heat transfer to the refractories

(iv) for a given rate of bath temperature rise, the rate of heat transfer to the refractories increases with furnace voltage.

There are three or four voltage and current combinations which will hold the furnace at temperature, depending on the condition of the furnace refractories.

From this work it is obvious that using the higher furnace voltages during refining results only in a waste of power, giving excessive refractory temperatures and severe erosion of the furnace side walls and roof. To maintain desired bath conditions, e.g. a rate of bath temperature rise of 5° C/min, there are probably two or three control settings that will serve the purpose. The choice of the right combination at any time will depend on the balance between thermal and electrical losses; other factors which may have to be considered are slag conditions, carbon pickup, and the efficiency of the electrode controllers.

HEAT TRANSFER INVESTIGATIONS DURING THE MELTING PERIOD

Roof temperature records taken during the melting periods of a number of first casts of the day all show the same general pattern. After ' power on,' there is little change of roof temperature until about 10 min have elapsed, when the temperature begins to increase steadily. At a period of 25–35 min after the start of the cast, depending on the power input being used, the rate of temperature rise suddenly begins to increase and within 5 or 10 min can increase from a rate of 10° C/min to one as high as 50° C/min. A typical record of roof temperature and rate of roof temperature rise, plotted against melting time, is shown in Fig. 1.

These observations and studies of heat transfer during refining, suggest that the time when the rate of roof temperature rise suddenly increases is when a large molten pool has formed in the centre of the bath and the arcs are no longer entirely surrounded by unmelted scrap. This would mean that the roof would be subject to direct radiation and convection from the arcs, and its temperature would shoot up accordingly.

To check on this theory, roof temperature records from first heats of the day with the same power input for melting were analysed and it was noted that for this particular input (2 300 A on the 180 V tap with 100% supplementary reactance in circuit) the sudden increase of rate of temperature rise occurred after about 25 min from the start of the heat. For these particular casts the power input was normally cut down after about 38 min, when it was found that most of the scrap charge was melted.

Using these records as a basis, several trial heats were conducted with the same power input for the early stages of the melting period, but when 25 min had elapsed the voltage was cut down to 88 V, the current remaining about the same.

The effects of this modified melting technique on roof temperature and rate of roof temperature rise during one particular cast are shown in Fig. 2. The effect on furnace performance was also studied.

Results

A study of the temperature records shows that cutting down the power input after 25 min had an immediate effect on the rate of heat transfer to the roof. For the example illustrated, the rapid increase of rate of roof temperature rise was checked and subsequently never reached a value higher than 35° C/min, which occurred about 4 min before melt-out. At melt-out the power was finally cut down to the normal refining value. For this particular heat the roof temperature at melt-out was only 500° C, compared with an average temperature of 847° C for casts where the high power was retained until the end of melting.

The effect on furnace performance is illustrated in Table II, where the results for melting time and energy consumption from four casts with the new melting technique are compared with those obtained during normal operation of the furnace on the 180-V tap. The roof temperatures at melt-out are also given.

It will be seen that the average melting time is 4 min longer for the test casts (that is, an increase of about 10%) but the energy consumption is reduced from 363 to 346 kWh (or 34 kWh/ton) which represents a saving of about 5%. The average roof temperature at melt-out is reduced by 221° C, from 847° to 626° C.

In the case of the 10-cwt experimental furnace the increase in melting time by using two different power inputs for melting is not important. (Of this time, 1 min is spent making the necessary voltage tap change.) However, the saving in electricity consumption is

TABLE II

Furnace performance during the melting period

Remarks	Cast no.	Time to melt out, min	Energy consumption, kWh	Roof temp. at melt out, °C
180 V 2 300 A used for complete melting period	B.128	36	328	630
	B.137	38	372	895
	B.143	37	358	—
	B.145	40	394	1 016
Means	4	38	363	847
180 V 2 300 A for first 25 min 88 V 2 700 A for rest of melting	B.213	42	345	660
	B.215	38·5	334	670
	B.216	43	353	675
	B.217	44	352	500
Means	4	42	346	626

appreciable. An analysis of roof temperature records obtained on production furnaces shows a similar trend to those obtained on the BISRA furnace, although in general the temperature levels are higher and there is more likelihood of leaving the high power on too long at the end of melting. If arc furnace roof pyrometry could be adopted as routine practice on production furnaces, then the potential savings in electricity and refractory costs by an informed approach to the control of power input would be considerable.

AUTOMATIC CONTROL OF POWER INPUT

The measurement of arc furnace roof temperature is beyond the scope of this paper and is to be dealt with elsewhere.* However, in passing, it should be mentioned that roof temperature measurement is routine practice on the BISRA 10-cwt furnace and is achieved by the use of Pt/Rh–Pt thermocouples. On continuously operated production furnaces, conditions are usually so severe that no suitable refractory material can be found to act as a thermocouple sheath and in these cases a radiation pyrometer can be used for measuring the temperature of the refractories. A typical pyrometer assembly which has been successfully applied to a production furnace is illustrated in Fig. 3.

Roof temperature investigations on the BISRA arc furnace and on production furnaces indicated the desirability of a method of controlling power input to the arcs by roof temperature, particularly for the automatic reduction of power input at the end of melting. An electrical circuit was designed and applied to the 10-cwt furnace so that when a predetermined roof temperature was reached at the end of melting the furnace voltage was automatically cut down to a lower value to safeguard the furnace refractories and prevent the wastage of electrical energy.

This method was used successfully for some months, but later, heat transfer investigations indicated the need for a more comprehensive controller. This led to the design of one which caters for the control of starting up the furnace, the end of melting, and the refining period.

*J. RAVENSCROFT: to be published.

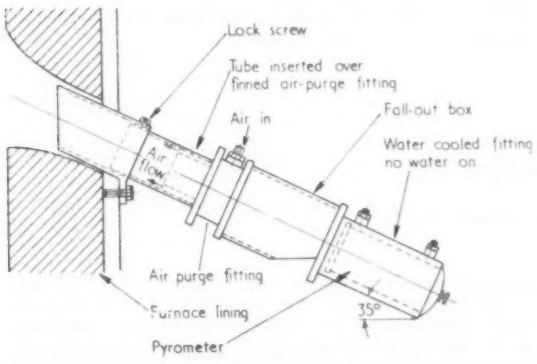

Fig. 3—Pyrometer assembly

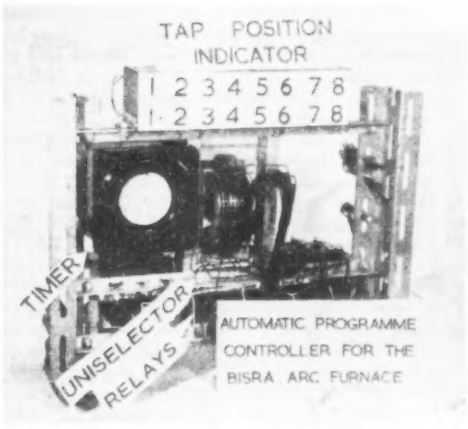
TAP POSITION INDICATOR
1 2 3 4 5 6 7 8
1 2 3 4 5 6 7 8
TIMER
UNISELECTOR
RELAYS
AUTOMATIC PROGRAMME CONTROLLER FOR THE BISRA ARC FURNACE

Fig. 4—Automatic programme controller

Function of the controller

The controller could be called a flexible programme generator, since it controls the order of events according to time and to the attainment of predetermined parameters, as measured by temperature and possibly radiation detectors fitted to the furnace. A potentiometric recorder/controller is used to measure the variable(s) and initiate control action, and is fitted with two sets of control contacts adjustable to different levels. A synchronous time relay is incorporated to give fixed time intervals and the heart of the controller is a two-direction stepping switch which is connected to form, with the furnace tap change gear, a switched servo-system in which the stepping switch is the master.

The stepping switch is actuated by both the interval timer and the temperature controller in the following way. On starting up, the furnace power and the controller are switched on and the stepping switch forces the tap change gear to select No. 5 voltage tap (110 V) in order to start melting at reduced voltage. After a suitable time interval, governed by the rate at which the electrodes bore down into the charge, the interval timer moves the stepping switch on, which causes the tap change gear to engage the highest (No. 8), voltage tap, at which stage the programme rests. When the roof temperature or radiation level reaches a predetermined value, which from experience denotes that the arcs are no longer entirely surrounded by unmelted scrap, the lower level temperature control contacts close. When these close the stepping switch selects the tap predetermined for use during the oxidizing period, in this case No. 3 voltage tap (88 V) which is used for the remainder of the melting period and for the first part of the refining period. The current is preset at the maximum permissible value during melting.

At this stage, further operation of the controller is governed by the maximum temperature control contacts. These are set at the lowest roof temperature found by practice to correspond to a power input capable of maintaining adequate bath temperature during refining, rather than at the maximum safe

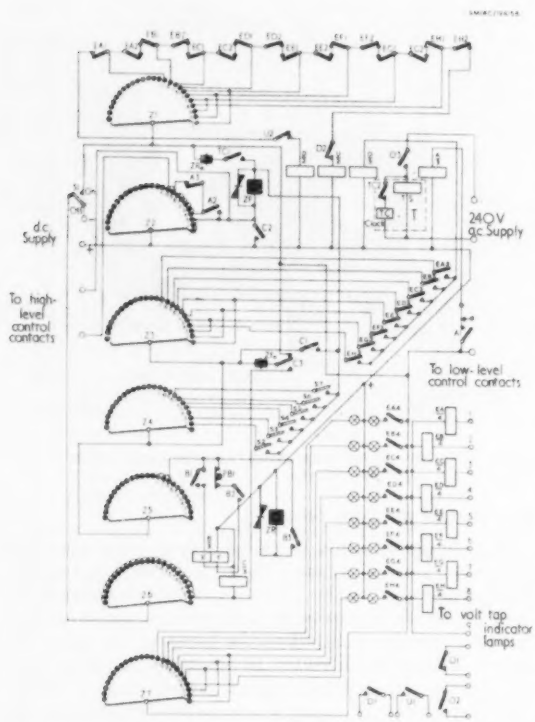

Fig. 5—Circuit for automatic programme controller

refractory temperature. Should the roof temperature subsequently exceed the level at which the maximum control contacts close, the stepping switch will again move and cause No. 2 voltage tap (75 V) to be selected, followed by operation of the interval timer to allow the roof temperature to fall and the maximum level contacts to open. If, at a later stage, the maximum roof temperature is again attained, then the stepping switch will cause No. 1 voltage tap (64 V) to be selected, after which it is thought to be probable, in the light of recent heat transfer measurements, that the current regulator should give adequate control.

Increased knowledge of heat transfer makes it desirable to leave only certain positions of the current regulator available to the melter during refining, and this facility can be incorporated in the design of the controller.

Provision has been made for controlling any size of furnace with on-load or off-load transformer tap change gear having any number of taps, and connection with any arc furnace should be relatively easy with a minimum of extra components. The precise nature of the extra components would depend on the make and design of the furnace to which the controller is to be fitted, but the specification of the controller itself would depend only on the number of transformer taps and whether on-load or off-load tap changing was fitted.

In the prototype controller, provision has been made for starting up the furnace and cutting down voltage step by step, or in large steps, and a push-button is fitted in order to allow reselection of a higher voltage if the furnace power has to go off for replacement of slag, etc., during the refining period.

Switching off the controller resets the programme to the starting point and this feature can also be used at the end of any melting period where the charge has to be added in more than one portion.

A prototype controller has been made (Fig. 4) and tested on the BISRA furnace, and negotiations are in hand to try the controller on a continuously operated production furnace. Information obtained from roof temperature and heat transfer investigations can be used for the manual control of power input, but a controller would do the job automatically and thereby give greater reliability.

In new designs of furnace electrical control systems the programme controller could be incorporated in the furnace control panel, and, if sufficient low voltage taps were provided, adjustment of current could be preset and the load regulator could be either omitted from the panel or reduced to a three position switch; low, medium, and high.

A full description of the electrical circuit and the mode of action of the controller is given in the appendix to this paper.

ACKNOWLEDGMENTS

The authors are indebted to the members of the Electric Process Sub-Committee of BISRA and the Electrical Engineers Group for their interest and guidance in carrying out this work; to Mr W. Bateman who was responsible for part of the experimental work and to the members of the Electric Furnace Section of the Steelmaking Division for their able assistance throughout the trials.

APPENDIX

Programme controller for regulating arc-furnace power input

Description of the prototype controller

The components used and the operation of the controller are described as follows and the circuit for the controller is given in Fig. 5.

The stepping switch is a both-way uniselector having eight levels and two 50-V d c operating coils. It is the master in a switched servo system in which the furnace transformer tap change gear is the slave. Relays *D* and *U* are the 'unbalance' detectors and the balanced state occurs when one of the relays *EA* to *EH*, corresponding to the preselected voltage tap, operates in parallel with the associated furnace tap position indicator lamp. Relays *EA* to *EH* are small a c relays, having 240-V coils. Relay

O causes closure of the furnace oil circuit breaker when it is in the operated state and when released causes the electrodes to rise and stop and the OCB to trip.

Relay *A* is operated by the low-level contacts on the roof temperature controller.

Relay *B*, when operated by push-button *PB*1, causes the stepping switch to back space one step each time the button is pressed.

Relay *C* operates when the controller is switched off at *S*1 to reset the stepping switch to step one in readiness for the next melt.

T is a synchronous timer with front setting dial, with a range of 0·5–20 min and consists of a solenoid *TS*, a synchronous clock *TC*, and two microswitches. The solenoid, when energized, engages the gearing of the clock drive which at the end of the timed period operates microswitches *TC*1 and *TC*2 in sequence. Contacts *TC*2 open circuit the clock to prevent self damage. De-energization of the solenoid resets the timer and contacts *TC*1 and *TC*2 return to their normal position.

Two sets of eight illuminated numerals are used to indicate the relative state of the tap change gear and the stepping switch. For instance, if the stepping switch lamp No. 5 and the tap change gear lamp No. 2 were on, relay *U* would be causing the tap change gear to rotate towards No. 5 tap. Coincidence would indicate normal working.

The programme is begun by switching on the power supplies to the controller.

A d c negative feed on uniselector level *Z*1 tests for a circuit between the junction of contacts *EE*1 and *EE*2 and relays *D* or *U* to the positive supply terminal. If either of these relays operate, then tap changing will proceed until relay *EE* operates and contacts *EE*1 and *EE*2 open, releasing either relay *D* or *U*, whichever operated.

Relay *D* causes tap changing downwards and relay *U* causes tap changing upwards, when operated.

At level *Z*3, contact *EE*3 completes a circuit for relay *O* to operate, energizing the oil circuit-breaker closing contactor coil through contacts *O*2. Contacts *O*3 close the timer circuit. After the interval has been timed, contacts *TC*1 close and cause the stepping switch to move on to step 2, the circuit being from the positive terminal to *Z*2 wipers, coil *ZF*, contacts *TC*1 and *ZRo* to the negative terminal. Relay *O* releases owing to the opening of contact *ZFo*, and the timer is reset to zero, opening contact *TC*1, de-energizing coil *ZF*. When relay *O* is released, contacts *O*1 close causing the electrodes to rise and stop breaking the arcs, when the OCB is tripped. The uniselector wipers are now on step 2 and at level *Z*1 relay *U* will be operated through contacts *EF*2, *EG*1, *EG*2, *EH*1, and *EH*2, and as soon as the OCB has tripped the tap change gear will rotate until the next highest voltage tap has been selected, when relay *EF* operates, releasing relay *U* at contacts *EF*2. Relay *O* is operated via contacts *EF*3, contact *O*3 restarts the timer, and contacts *O*2 cause the OCB to re-close.

This process continues until step 4, corresponding to tap 8 the highest voltage, is reached after which the timer restarts as usual and contact *TC*1 closes as before at the end of the time interval. However, now the stepping switch will not move until contact *A*2 closes by the operation of relay *A* at the approach of the end of the melting period.

Operation of relay *A* on closure of the low-level contacts of the temperature controller initiates the second part of the programme which deals with reduction of power input at the approach of the end of the melting period. Contact *A*2 closes causing the stepping switch to move to step 5, corresponding to the No. 7 voltage tap. The voltage taps 7 to 3 are selected at timed intervals, halting at tap 3 which is used for the end of melting and the start of the refining period. Contact *A*3 permits the maximum temperature control contact to override the low-level contacts. Relay *A* on operating holds via contact *A*1.

Control during the refining period depends on operation of the high-level roof temperature control contacts, and when these close the stepping switch is moved on one step by energization of coil *ZF* through *Z*2, step 9 and contact *TC*1, which closes after the timed interval.

After the stepping switch has moved from step 9 to 10, the timer will prevent a further reduction of voltage until the end of the interval to give the roof temperature time to fall and the roof temperature controller high-level contacts time to open.

Resetting of the programme during the refining period, to allow extra power to be used for melting the second slag, or for other purposes, is done by reversing or back spacing the uniselector as follows.

When push-button *PB*1 is pressed the normally open contacts close and energize one coil *X* of relay *B* which operates, holding over contacts *B*1; a release circuit is also prepared at contact *B*2. Contact *B*3 completes the circuit for coil *ZR*, and the stepping switch moves back one step. *ZRo* contacts prevent energization of coil *ZF*. On returning to the rest position, the normally closed contacts of the push-button cause energization of the release coil *Y* of relay *B*, which is released, thus opening both coil circuits simultaneously, and *B*3 opening de-energizes coil *ZR*. This facility is available on steps 9, 10, and 11.

Switching off causes operation of relay *C*, which at contacts *C*1, *C*2, and *C*3 places contact *ZFo* in series with stepping switch level *Z*6 and coil *ZF* across the 50-V d c supply which results in forward homing to step 1, where relay *C* is then released.

The starting sequence or the reduction of voltage towards the end of melting can be modified so that any tap or all taps intermediate between taps 5 and 8 on starting and taps 8 and 3 cutting down, may be omitted by the use of switches *S*2 and *S*7. The timer can be set externally from the front of the case for time intervals between 0·5 and 20 min and separate timers could be used if experience shows this to be desirable.

Supplies for the controller are 50 V d c for the both-way uniselector, relays *A*, *B*, *C*, *D*, *O*, and *U*, and the indicator lamps, and 240 V a c for the synchronous timer. Relays *EA* to *EH* are fed from the furnace tap change panel, in parallel with the existing tap position indicator lamps. The controller indicator lamps are connected to level *Z*7.

Consideration is being given to the construction of a controller using all a c components.

Provision can be made for locking out certain positions on the load regulator for voltage taps normally used for refining, in order to assist the melter in selecting the best conditions for optimum heat transfer to the bath.

Pelletizing before sintering: some experiments with a disc

By F. D. Ball, B.Sc.

SYNOPSIS

The installation of a disc pelletizer at the BISRA north-east coast laboratories has provided valuable data on the effect of prepelletizing upon the sintering characteristics of both home and foreign ore mixes. The results have shown that pellets below $\frac{1}{8}$ in. are to be avoided and that the fuel can be most profitably introduced to the sinter mix after pelletizing. A material previously regarded as deleterious in the sinter process, due to its fine particle size, has been introduced to the sinter mix in the form of pellets without affecting the sintering permeability. The disc has also been installed in the feeder bay of an existing sinter plant to permit continuous operation and throughput tests have been carried out both on the laboratory and works scale. The effect of disc angle and speed upon both the pellet production rate and distribution within the disc have been investigated. The influence of disc shape and form of scraper used upon subsequent output and power requirement have formed the subject of a limited series of experiments. A guide to the increase in power requirement with disc size has been formulated. Notable limitations on the effectiveness of the disc pelletizer in dealing with extremely fine or harsh material have been observed.

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THE CONDITIONING of sinter plant feeds is an important factor in determining the output rate from a sinter strand and considerable attention is being given to this problem both in the UK and the USA. The improvements in average sintering permeability resulting from pelletizing iron ore fines before sintering have been described in previous papers. Grice and Davies[1] pelletized Frodingham-Northants mix in a 'drum-type' pelletizer and sintered the product both in an experimental box and on a Greenawalt plant; considerable improvement in permeability was observed when operating with a coke-coated pelletized feed. Lang and Sirs[2] using Sydvaranger concentrates showed that for a given suction the output of finished sinter could be more than doubled by pelletizing a lime-conditioned mix on a shaker board. Nearly half of this improvement was attributed to the effect of pelletizing.

The literature published to date is concerned mainly with pelletizing or conditioning sinter feeds in revolving drums. Disc pelletizers have been used in the cement industry for several years and in isolated cases for pelletizing ore fines, the main advantage being claimed for the disc is that it classifies the product. Discs are now extensively installed in the USA for prepelletizing sinter plant feeds, but there is not, as yet, data published on the design and performance of these units. The question of using drum pelletizers is being actively pursued in the UK and the success of the experimental work has already led to the installation of this feature in one sintering plant.[3] However, no attempt has previously been made in the UK to assess the suitability of disc pelletizers for prepelletizing sinter plant feeds and this prompted the present investigation; at the same time some effort has been made to answer more fundamental questions regarding the role of prepelletizing in sintering irrespective of which machine is used for this purpose.

In March 1956 the UK agents for the German firm of Loesche loaned the Iron Making Division of BISRA a 1-m dia. experimental disc. In view of the results obtained by Davis[4] with this disc it was decided to install a 5-ft dia. disc at the Redcar experimental station.

As a result of approaches by sinter plant managements interested in assessing the potential of pelletizing as a means of improving the average sintering permeability in their specific practice, experimental work to date has been largely concentrated on two sinter mixes. These tests have answered important questions: what is the best pellet size, and, is it more profitable to introduce coke and return fines before or after the pelletizer?

Some difficulty was experienced initially with promising materials, and this prompted a short study of the behaviour of material in the disc and those conditions under which the disc could be expected to act as a classifier. In conjunction with this, note was made of the power used by the disc and these results have enabled a rough estimate to be made of the power required by larger discs.

The pellets used during the sintering tests were generally produced by continuous operation but this was necessarily short in duration owing to the limited bunkering and feeding arrangements at the pilot plant. To assess the capabilities of the disc more accurately, installation on an operating sinter plant was required and this facility became available in April 1958. During the intermediate period between the initial tests and the plant installation other factors such as disc shape and scraper position were investigated.

DESCRIPTION OF APPARATUS AND EXPERIMENTAL PROCEDURE

The apparatus, shown in Figs. 1 and 2, consists of a 5-ft dia. disc with a $9\frac{1}{4}$-in. lip mounted on a shaft coupled to a reduction gearbox. The gearbox is driven by a 2-h p 1 430 rev/min 3-phase electric motor through a variable-speed pulley. Speed variation is obtained by altering the belt tension by means of a screw adjustment supporting the motor. This gives a disc speed range of 16–32 rev/min. The selection of high disc speeds in combination with low

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The author was a member of the Iron Making Division of the Association and is now Assistant in Chemistry at the University of Aberdeen.

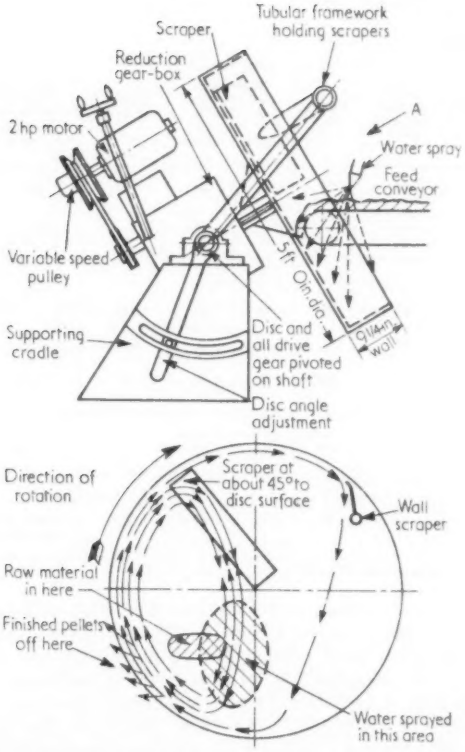


Fig. 1—Diagrammatic arrangement of disc pelletizer

disc angles to the horizontal is limited by the horsepower rating of the electric motor and gearbox.

The disc and drive equipment are supported on a common tubular support together with two scrapers. The support fits into two plummer blocks bolted to the main cradle. The disc can be maintained at any desired angle between 25° and 65° to the horizontal by a lever coupled rigidly to the supporting shaft and held by means of a nut in the slide attached to the cradle.

There are two scrapers; one for the disc surface and one for the wall, each capable of independent adjustment. Water is usually added to the material on the disc by two compressed-air atomized water sprays, although in some experiments and in the plant installation a rectangular ' rose ' 6 in. high and 1 in. wide has been used. In later experiments a rotameter was used to measure the water input rate. In the pilot plant the raw material is fed into the disc by a belt conveyor, hand loaded from buckets containing a weighed amount of material. The conveyor belt is marked off into sections 18 in. long by white lines; each bucket of material is evenly distributed over a given number of sections thus ensuring a steady input rate to the pelletizer.

Throughout the tests further additions to the pellets (return fines, moisture, and coke) were made by hand mixing on the floor and the resultant sinter mix was loaded into the ' segregated feed box ' (area 4 ft²) to give a bed height of 12 in. The ignition time was 60 s at a coke-oven gas flow of 7·5 ft³/min/ft² of bed area (calorific value of gas 467 Btu/ft³) giving an ignition intensity of 3 500 Btu ft²/min and a total heat input of 3 500 Btu/ft². Throughout ignition the airflow through the sinter box was controlled to give a previously established optimum atmosphere above the bed. After ignition the suction under the bed was increased to 15 or 20 in. w g depending on the mix, and maintained at that value throughout sintering. In tests involving a sinter mix of very high permeability it was not possible to maintain the suction during the later part of the test, since the orifice differential would have exceeded the height of the gauge. The suction under the bed, airflow, and

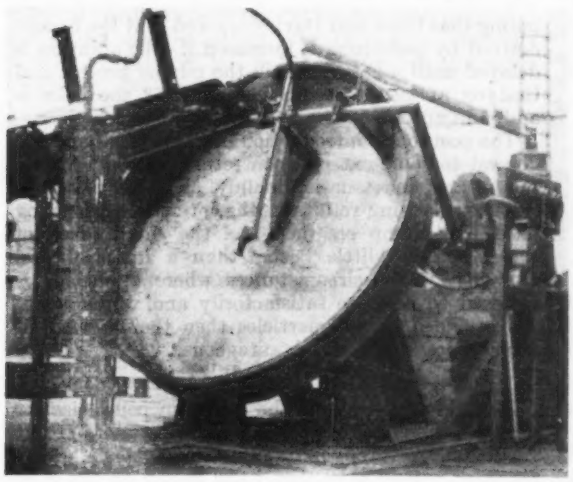


Fig. 2–Disc pelletizer

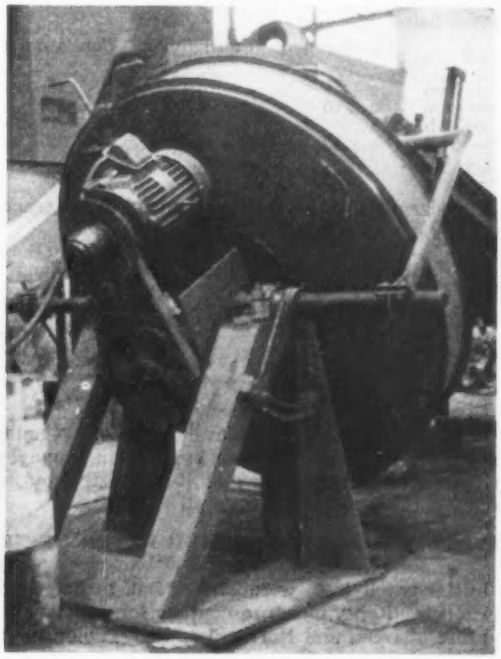


TABLE I
Initial series

Combination	Average sintering permeability, Bpu	Sintering air, ft³/ton of raw mix	Strength index	Circulating load, %	Bulk density raw mix, lb/ft³	Yield, %	Raw mix composition dry basis, % coke	Raw mix composition dry basis, % C fines	Overall moisture, %	Sintering time for 15-in. wg suction, min
(1) Ores only pelletized, coke returns mixed in separately on the floor	140	39 600*	66	30	82	71	6	34	12	10
(2) Ores and coke mixed and pelletized, return fines mixed separately on the floor	129	39 300	63	30	84	72	6	34	12	10·5
(3) Ores pelletized, coke added and repelletized, returns mixed separately on the floor	148	38 100	62	30	84	71	6	34	12	
(4) Ores and returns mixed and pelletized, coke mixed in separately on the floor	136	40 100	67	29	83	70	6	33	12	10·5
(5) Ores and returns mixed and pelletized, coke added simultaneously in pelletizer	135	39 400	53	30	82	70	6	34	12	10
(6) Unpelletized	87	37 200	65	30	82	70	6	34	12	12 at 20-in. wg suction

* Mean value from subsequent tests 40 800 ft³/ton

temperature of the waste gases leaving the bed were measured every minute.

MATERIALS USED

Two sinter plant mixes have been used for the sinter box tests. The first consisted of a 2 : 1 mixture of Lincs and Northants ore and the second of a 6 : 3 : 1 mixture of Swedish, mixed soft, and Cleveland ores, known as 'Cleveland mix.'

The Lincs and Northants ore arrived in three separate consignments, of moisture about 12%. Size analyses of the 2 : 1 mixture sieved below ½ in. are shown below:

	Consignment 1, %	Consignment 2, %	Consignment 3, %
+ ¼ in.	8	10	10
− ¼ in.	16	17	16
+ ⅛ in.			
− ⅛ in.	19	20	22
+ 1/16 in.			
− 1/16 in.	57	53	52

The size analyses of the constituents of the second mix are shown in the following table:

	Swedish	Soft ore	Cleveland	Swedish: Soft: Cleveland 6 : 3 : 1
+ ¼ in.	31	14	26	25
− ¼ in.	20	21	19	20
+ ⅛ in.				
− ⅛ in.	14	19	18	16
+ 1/16 in.				
− 1/16 in.	35	46	37	39

In all the sintering tests Cleveland coke, rod milled to − ⅛ in., was used. In those experiments involving Sydvaranger concentrates and flash-roasted pyrites residues, these materials were all − ⅛ in.

INTRODUCTION OF COKE AND RETURN FINES TO THE SINTER MIX

Initial batch tests were carried out to determine the most suitable moisture content for pelletizing a mixture of Lincs and Northants fines. The optimum moisture content was found to be 16%, pelletizing taking place in the range 15–17% moisture content. Tests were then carried out to determine the most suitable combination of material to pelletize, i.e. whether it is better to add the return fines or coke before or after pelletizing. The results of these tests shown in Table I indicate that in every case pelletizing increases the average sintering permeability; pelletizing the ore, adding the coke, repelletizing, and then mixing in the return fines by hand produces the best results, with pelletizing the ore alone and hand mixing with the coke and return fines the next best. Since on plant scale, repelletizing in a disc to introduce the coke would require considerably more equipment, and as the improvement gained by the second run through the pelletizer is small, it was decided to concentrate further tests on pelletizing the ores alone, adding coke and return fines separately by hand. It is worthwhile noting that Grice and Davies[1] showed that the benefit derived by pelletizing is increased if coke addition is delayed until a later stage in the mixing process and that on at least one US installation,[5] the coke is added in an outer annulus built into the pelletizer.

The position of introduction of the return fines will depend to some extent upon return fines quality; if the return fines consist mainly of small pieces of sinter, pelletizing results in the interstices becoming filled with damp ore fines and the small piece of sinter becomes little better than a lump of ore. However, under circumstances where a nucleus is required to pelletize satisfactorily and when this is not provided by ore particles then the presence of return fines would be advantageous.

OPTIMUM PELLET SIZE FOR SINTERING

In order to determine the optimum pellet size for sintering, several tests using Lincs–Northants ore at varying disc throughputs were carried out. The resultant pellets were then hand mixed on the floor with 34% return fines and 6% coke (dry bases), the

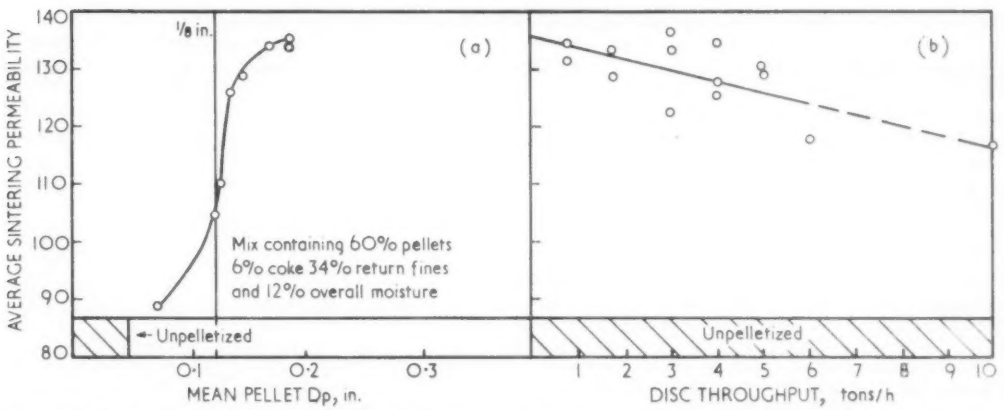


Fig. 3—Lincs–Northants mix, (*a*) relationship between average sintering permeability and pellet size, (*b*) relationship between sintering permeability and disc throughput

overall moisture being made up to 12% by the addition of water to the return fines before mixing. In all cases a sieve analysis was carried out on a sample of the pellets. The mean size[6] of these pellets was calculated according to the expression

$$D_p = \frac{\Sigma X_i}{\Sigma(X_i)/(D_i)}$$

where D_p is the average diameter and X_i is the fraction by volume occupied by solids having the diameter Di. The dependence of average sintering permeability on mean pellet size is shown in Fig. 3*a* and indicates that there is a sharp fall in average sintering permeability for sinter mixes containing pellets for which the mean size is less than $\frac{1}{8}$ in. Pelletizer operation must therefore be such as to produce pellets containing the minimum $-\frac{1}{8}$-in. fraction. However, too large pellets are undesirable since they would form poorer sinter, and probably reduce disc throughput. A valid criterion for disc operation is, then, the production of a minimum of $-\frac{1}{8}$-in. pellets, together with a maximum production in the size range $\frac{1}{8}$–$\frac{1}{4}$ in. Some variation in the optimum size, however, may occur due to variability of return fines composition. Hamilton and Ameen[7] have shown that best sinter production was obtained when all pellets less than 0·132 in. (US Screen Scale No. 6) were eliminated.

EFFECT OF DISC ANGLE AND SPEED ON PELLET SIZE

The effect of these variables using Lincs and Northants ore and a throughput of 2 tons/h are shown:

Effect of disc angle (*speed* 24 *rev/min*)

	Angle to horizontal		
	45°	50°	55°
$+\frac{1}{4}$ in.	69	59	30
$-\frac{1}{4}$ in. $+\frac{1}{8}$ in.	23	31	52
$-\frac{1}{8}$ in. $+\frac{1}{16}$ in.	6	8	14
$-\frac{1}{16}$ in.	2	2	4
D_p in. (mean pellet size)	0·23	0·21	0·16

Effect of disc speed (*angle to horizontal* 55°)

	Speed, rev/min			
	20	24	28	32
$+\frac{1}{4}$ in.	34	30	33	50
$-\frac{1}{4}$ in. $+\frac{1}{8}$ in.	50	52	53	38
$-\frac{1}{8}$ in. $+\frac{1}{16}$ in.	11	14	12	10
$-\frac{1}{16}$ in.	5	4	2	2
D_p in. (mean pellet size)	0·16	0·16	0·18	0·20

These tests were carried out using a single water jet, the water being atomized to a similar degree in each case. It is clear that disc angle and speed have an effect upon resultant pellet size, larger pellets being produced for settings which give the material the greatest number of revolutions during its residence period.

EFFECT OF DISC THROUGHPUT

The effect of disc throughput has been investigated for the Lincs–Northants mix up to a maximum of 6 tons/h using a disc angle and speed of 45° and 24 rev/min. Further tests were carried out at a higher disc speed but the limitation on motor horsepower made it necessary to increase the disc angle; it was found, however, that these alterations in angle and speed made very little difference to the results. For experiments at higher throughput rates, moisture control is particularly difficult; since tests involving 600 lb of ore in some cases take appreciably less than 4 min, this allows very little time to establish the correct water adjustment.

As a result the apparatus was modified by the introduction of a rotameter to measure the water input rate and two air jets to give better control of air atomization. This has resulted in considerable improvement, pellets of mean size 0·16 in. now being produced at a throughput rate of 6 tons/h. With this improved technique the average sintering permeability was determined for mixes containing pellets produced at up to 5 tons/h throughput. A further test was then carried out using a disc throughput rate of 6 tons/h, the size analysis of the pellets produced being $+\frac{1}{4}$ in. 61%; $-\frac{1}{4}$ in. $+\frac{1}{8}$ in. 22%; $-\frac{1}{8}$ in. $+\frac{1}{16}$ in. 9%; and $-\frac{1}{16}$ in. 8%. These pellets, when mixed with coke return fines, gave an average sintering permeability of 134 Bpu but considerable coke segregation resulted in a layer of unsintered material at the bottom of the bed and a high return fines output. To minimize coke segregation and yet retain the advantages of a good ignition layer a further test at a throughput rate of 6 tons/h was carried out adding half the coke in the pelletizer and the other half by hand. The presence of coke in the pelletizer results in the production of inferior pellets and the resultant average sintering permeability was 118

TABLE II—Various parameters averaged for different throughputs

Throughput, tons/h	Average sintering permeability, Bpu's	Air, ft³/ton	Pre-ignition permeability, Bpu s	Strength index	Return fines make, %	Sintering time, min	Average pellet size, in.
1	134	44 800	168	64	34	11½	0·21
2	132	40 600	163	65	36	10½	0·17
3	131	41 700	170	63	35	11½	0·13
4	130	40 000	172	63	35	10½	0·12
5	130	39 300	174	66	35	10½	0·13
6	118	38 600	160	70	36	11½	0·08
Unpelletized material	87	37 200	106	65	34	14 (Recalculated for 15-in. wg suction)	0·05

Bpu with a balanced circulating load of 30%. One further test was carried out at a throughput rate of 10 tons/h mixing half the coke with the pellets. Very poor quality pellets, in fact little more than wet lumps, were produced: the size range was considerable, some pellets being greater than $\frac{3}{4}$ in. When loaded into the segregated box these large pellets formed a hearth layer which did not sinter but was only calcined: despite this, the quality of the sintered material was good, the return fines make being 32% and the strength comparable with that made from unpelletized ores. The average sintering permeability was 117 Bpu and the air per ton of raw mix was 34 700 ft³.

During this test the auxiliary equipment to the pelletizer was working at its maximum rate and control of ore and moisture input rates was very difficult: in consequence considerable emphasis should not be placed on this result. Values of average sintering permeability against disc throughput rate are shown in Fig. 3*b* and the regression line of average sintering permeability on disc throughput has been drawn for the range 1–6 tons/h. It is interesting that the value for a throughput of 10 tons/h lies on the extrapolated regression line. The values of important parameters for the thirteen tests shown in Fig. 3*b* have been averaged for each disc throughput rate and are shown in Table II together with the result for unpelletized material. In all these tests the dry mix composition was 60% 2 : 1 Lincs–Northants fines, 6% coke, 34% return fines, and 12% overall moisture. The return fines make has been calculated on the same basis as the input return fines so that a value of 34% would be equivalent to a balanced circulating load of 30%. During those tests, for throughputs of up to 4 tons/h, air atomization was kept roughly constant and it was noted that the pellets produced were becoming too small to obtain maximum benefit from pelletizing. At this stage the degree of atomization was reduced and this resulted in the production of larger pellets. Little was then known about the effect of water atomization and the position of water introduction to the disc but it is clear that these two factors are, for a given material, important variables affecting pellet size.

THE EFFECT OF PELLETIZING ON THE PERMEABILITY OF A CLEVELAND MIX

Tests by Davis[4] suggested that the Cleveland mix was not amenable to disc pelletizing. These experiments were carried out on the ores and return fines combined, the ore fraction alone, and the $-\frac{1}{4}$-in. fraction of the ore. In no case was any pellet formation apparent but it was observed that there was an overall increase in particle size due to loose attachment of fine materials to the larger particles; this will be referred to as aggregation, as distinct from pellet formation. Before this series, tests had been carried out using a small cement mixer in an attempt to prepelletize a sample of Cleveland mix; no pellets were formed but there was an improvement in the pre-ignition permeability and a slight reduction in the sintering time. When a 5-ft disc became available it was decided to perform a more exhaustive series of tests on this mix paying particular attention to improvements in average sintering permeability without laying undue emphasis upon disc performance.

Initial tests were carried out to determine which of the constituent ores would pelletize satisfactorily; it was found that only with Cleveland and soft ores could pellets be obtained. Size analyses for the unpelletized and pelletized ores are given in Table III.

In the first tests carried out it was decided to use $-\frac{1}{2}$-in. return fines from previous tests and to try to achieve a roughly balanced circulating load.

In the first test with an input return fines of 39½% the returns make was 43% and it was considered that this was sufficiently close to justify maintaining 39½% return fines in further tests. The sintering time for unpelletized material was 13½ min using 20-in. w g suction. The Cleveland and soft ores were then pelletized separately and hand mixed with the Swedish and return fines. Only very small improvement in sintering permeability was obtained, which is not unexpected since only 40% of the total ore was pelletized and the large amount of fines in the Swedish ore might well fill up most of the voidage created by pelletizing the minor constituents. Treating all the ore together in the disc gave an aggregating effect, the abrasive $+\frac{1}{4}$-in. material impeding good pellet formation, but since this aggregation gave a larger overall particle size this mix was sintered and gave a small reduction in sintering time.

Since prepelletizing for sintering tests on the Lincs–Northants mix indicated that best average sintering permeability was obtained with all ore pelletized to just over $\frac{1}{8}$ in., the $-\frac{1}{8}$-in. fraction of the ores was sieved out and attempts made to pelletize it to $+\frac{1}{8}$ in. In the absence of the abrasive action of the

TABLE III

Size analysis for pelletized and unpelletized ores

in.	Cleveland		Soft ore	
	before pelletizing, %	after pelletizing, %	before pelletizing, %	after pelletizing, %
$+\frac{1}{4}$	26	28	14	22
$-\frac{1}{4}+\frac{1}{8}$	19	44	21	35
$-\frac{1}{8}+\frac{1}{16}$	18	26	19	35
$-\frac{1}{16}$	37	2	46	7

larger materials it was found that the $-\frac{1}{8}$-in. fraction of the mixed ores could be satisfactorily converted into hard well-shaped pellets. A mix of which the $-\frac{1}{8}$-in. fraction had been pelletized was then sintered, but despite an improvement in pre-ignition permeability there was no improvement in average sintering permeability.

In view of the low permeability of the finished sinter (about 120 Bpu) it became clear that using $-\frac{1}{2}$-in. return fines, the average permeability was not greatly different from the final value and as a result considerable improvements could not be expected. Further tests were therefore carried out using about 40% $-\frac{1}{4}$-in. return fines which is more in accord with plant practice. On this sinter plant a considerable percentage of the return fines results from the severe action of the claw disintegrator and since this cannot be simulated on an experimental box, a circulating load balance is not, in this instance, to be expected. An initial test with unpelletized material and $-\frac{1}{4}$-in. return fines gave a sintering time of $18\frac{1}{2}$ min ; further tests, first aggregating all the ores, and second pelletizing the $-\frac{1}{8}$-in. fraction of the ore gave sintering times of $16\frac{1}{2}$ and $14\frac{1}{2}$ min respectively. These sintering times with unpelletized and aggregated material are in good agreement with those results obtained using a cement mixer for aggregation. It is clear that under these conditions reasonable reductions in sintering time could be brought about by pelletizing the $-\frac{1}{8}$-in. fraction of the mix, but the practical difficulties of carrying this out on the full scale would be considerable. The results of these sinter box tests are shown in Table IV.

INTRODUCTION OF VERY FINE MATERIALS INTO A SINTER MIX

Pelletizing has been regarded primarily as a potential means of increasing the production of sinter plants by increasing the permeability of the mix. It does, however, seem feasible that it could be used as a means of introducing to the sinter mix materials, in the form of pellets, previously regarded as deleterious because of their small particle size. The increase in sintering time resulting from small additions of flash-roasted pyrites to sinter mixes is well known and is illustrated by two tests in which 5 and 10% additions of flash-roasted pyrites have been made to the Cleveland mix. These show markedly adverse effects on the sintering time corresponding to a percentage loss in output of the order of twice the percentage addition. Introduction of flash-roasted

TABLE IV

Results of sinter box tests

	Raw mix composition, %					Overall moisture	Sintering time, min	Average sin. perm. Bpu's	Pre-ignition perm. Bpu's	Air, ft³/ton	Return fines make, %	Strength index	Yield, %
	Cleveland	Swedish	Soft ores	R. fines	Coke								
Return fines $-\frac{1}{2}$ in. Unpelletized	5·6	33·6	16·8	39·5	4·5	7	$13\frac{1}{2}$	90	139	31 600	43	58	85
Cleveland and soft ore pelletized	5·6	33·6	16·8	39·5	4·5	7	13	94	143	31 000	45	64	83
Mixed ores treated in disc	5·6	33·6	16·8	39·5	4·5	7	$12\frac{1}{2}$	100	176	31 500	47	68	86
$-\frac{1}{8}$-in. fraction of mixed ores pelletized	5·6	33·6	16·8	40·0	4·0	$6\frac{1}{2}$	13	90	150	30 600	50	69	86
Return fines $-\frac{1}{4}$ in. Unpelletized	5·6	33·6	16·8	39·5	4·5	7	$18\frac{1}{2}$	69	120	32 500	21	68	82
$-\frac{1}{8}$-in. fraction of mixed ore pelletized	5·6	33·6	16·8	39·5	4·5	7	$14\frac{1}{2}$	80	149	30 200	28	57	87
Mixed ores treated in disc	5·6	33·6	16·8	39·5	4·5	7	$16\frac{1}{2}$	74	140	31 000	21	63	85
Cleveland sinter plant raw mix Untreated						7	$18\frac{1}{2}$	64	70	29 800	...	69	83
Treated in a cement mixer						7	16	69	122	27 200	...	62	83
Flash-roasted pyrites additions 5% Unpelletized	5·1	30·6	15·3	39·5	4·5	$7\frac{1}{2}$	20	59	93	30 400	24	64	85
5% Pellets	5·1	30·6	15·3	39·5	4·5	$7\frac{1}{2}$	18	62	105	29 000	24	68	84
10% Unpelletized	4·6	27·6	13·8	39·5	4·5	8	$24\frac{1}{2}$	52	77	30 700	28	64	83
10% Pellets	4·6	27·6	13·8	39·5	4·5	$7\frac{1}{2}$	19	59	100	28 900	22	70	84

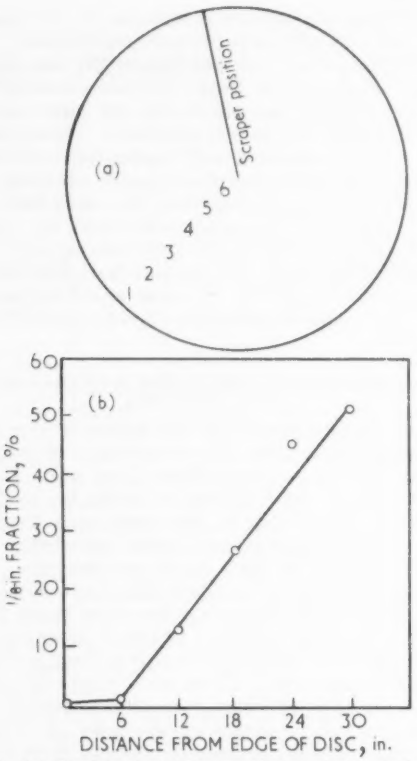


Fig. 4—(*a*) Positioning of sampling points used when investigating pellet distribution within the disc, (*b*) distribution of $-\frac{1}{8}$-in. fraction across the disc for a disc speed of 17 rev/min and angle of 65°, using flash-roasted pyrites

pyrites in the form of pellets ($+\frac{1}{2}$ in. 26%; $-\frac{1}{2}$ in. $+\frac{1}{4}$ in. 38%; $-\frac{1}{4}$ in. $+\frac{1}{8}$ in. 19%; $-\frac{1}{8}$ in. 17%) produced from the pelletizer at a throughput rate of 2 tons/h have resulted in no increase in sintering time.

PELLETIZING FLUE DUST

The addition of large quantities of flue dust to the sinter mix may be restricted because the small particle size reduces the permeability of the mix. Because of its high carbon content, if flue dust is to be pelletized, either very small pellets must be made or alternatively the flue dust must be mixed with a coke-free material to reduce the carbon content. Attempts to pelletize flue dust resulted in poor pellets which were very weak, variable in size, and they took a considerable time to form in the disc. Further experiments mixing flue dust with 50% of flash-roasted pyrites or 50% Northants gave large pellets which were difficult to form. The addition of 2% bentonite to the flue dust, on the batch scale resulted in small pellets of excellent quality but a continuous run showed that an output of less than 1 ton/h was to be expected. It seems likely that the poor pellets obtained are due to the adverse effect of coke upon pelletizing.

PELLET DISTRIBUTION WITHIN THE PELLETIZER

Water addition within the disc pelletizer is one of the important variables affecting the production of good closely sized pellets. In the series of tests using Lincs–Northants fines all the material was lifted to the top of the disc and then diverted by the scraper to the bottom, a large unused vortex being created in the centre of this revolving mass. While this has the advantage that all the material is subjected to the maximum number of revolutions during its residence time in the disc, it has certain disadvantages: first, the pelletizer ceases to classify those pellets thrown from the disc, second, water addition is made to the whole of the ore stream thus encouraging the larger pellets to grow further, third, the system has a high power consumption. In this initial case of a clay-like material which pelletizes very easily these disadvantages are probably outweighed by the need to obtain the maximum number of revolutions during the residence time of the material and consequently to obtain a high output. However, in the case of dry powdery materials which do not pelletize so readily and which have a very low permeability in the raw state, the production of good pellets containing only a small fraction of unpelletized material is of paramount importance; water additions should be made at points in the disc where the concentration of unpelletized material is a maximum, and in addition, full use must be made of the disc for classifying the product. Little was known of the distribution of pellets within the disc and of its dependence upon disc angle and speed, and the following investigation was undertaken in an attempt to obtain an understanding of the behaviour of material within the disc.

Initial test on flash-roasted pyrites

Early attempts to pelletize flash-roasted pyrites were unsuccessful due to failure to appreciate the advantages to be gained from running the pelletizer at a low speed and adding the water at the correct point. To aid good pellet segregation across the disc the scraper was adjusted to a position only a few degrees from the vertical diameter of the disc. For flash-roasted pyrites the range of moisture content in which pelletizing takes place is very small and in the early unsuccessful tests as soon as pellets were formed they were coated with more water and quickly built up to sizes greater than an inch. On reducing the water supply in an attempt to control the pellet size the material became too dry to pelletize and a mixture of very large pellets and unpelletized material was thrown from the disc. The disc angle was therefore increased and the disc speed reduced so that only the small particles were carried to the top of the disc; these particles either fell or were diverted by the scraper down the centre of the disc where water additions were made to this material only, by means of a rectangular ' rose ' about 6 in. long and 1 in. wide. As the disc speed was insufficient to carry the large pellets away from the bottom of the pelletizer these were the ones which were thrown from the disc.

At a favourable time during the tests samples of pellets were taken by hand from six points along the radius of the disc shown in Fig. 4*a*. These points were selected at distances of 0, 6, 12, 18, 24, and 30 in. from the edge of the disc, the last point of course being the disc centre. These samples were sieved on an $\frac{1}{8}$-in. screen and the distribution of the $-\frac{1}{8}$-in.

material across the disc is shown in Fig. 4*b*, for a disc speed and angle of 17 rev/min and 65°. At the edge of the disc there is no unpelletized material present and this is the material which will next be thrown from the disc as more raw material is added. The material at the centre of the disc (position 6), to which the water is being added, contains a higher concentration of unpelletized material than at any other point in the disc.

Flash-roasted pyrites are unsuitable for an investigation of pellet distribution under a variety of conditions since with an unsuitable disc angle and speed, steady operation cannot be attained.

Distribution with Sydvaranger concentrates

In view of the large quantities of ore required for continuous operation further tests were carried out using the disc as a batch pelletizer.

Using Sydvaranger concentrates and operating the disc at what appeared to be a favourable angle and speed (55° to the horizontal and 18 rev/min) six samples were taken across the disc and size analysed on $\frac{3}{8}$-in., $\frac{1}{4}$-in., $\frac{1}{8}$-in., and $\frac{1}{16}$-in. screens. From this the percentage less than $\frac{1}{8}$ in. and the average pellet size was calculated for each position. The results are represented graphically in Fig. 5. It was soon apparent that in dealing with a system where pellets in the disc are getting larger with the passage of time, results obtained following adjustments to the disc cannot be compared with those obtained an instant previously. To prevent this a mixture of four parts of Sydvaranger concentrates and one part Portland cement was batch pelletized and the resultant product spread over a large area and allowed to harden for two or three days. The pellets were then sieved and 100 lb of the

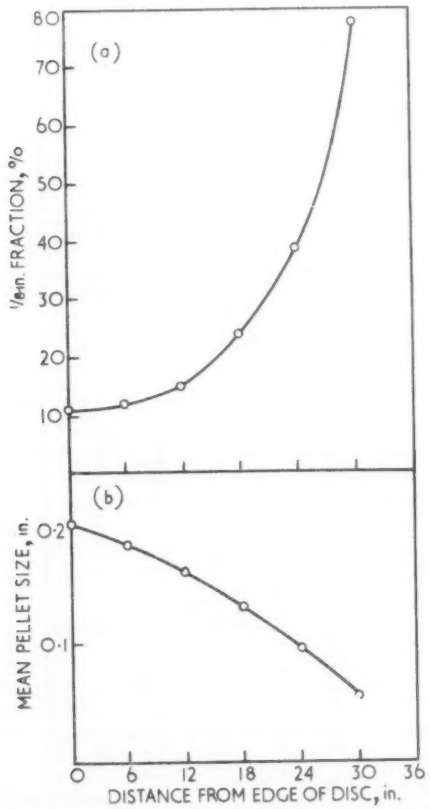


Fig. 5—Distribution of (*a*) − $\frac{1}{8}$-in. fraction and (*b*) mean pellet size for a disc speed of 18 rev/min and angle of 55°, using Sydvaranger concentrates

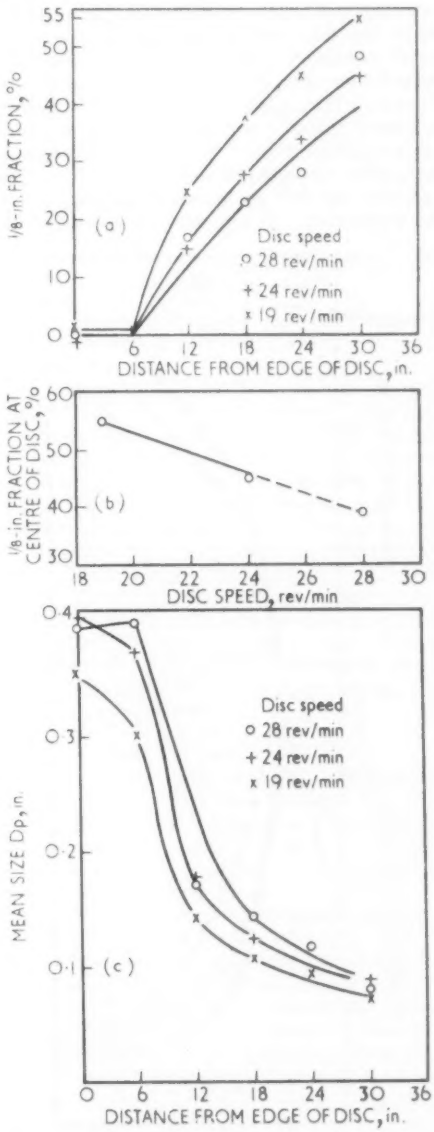


Fig. 6—Sydvaranger (cement-hardened) pellets, relationship between (*a*) disc speed and distribution of − $\frac{1}{4}$ + $\frac{1}{8}$-in. fraction, (*b*) disc speed and concentration of − $\frac{1}{4}$ + $\frac{1}{8}$-in. fraction at centre of disc, (*c*) Distribution of pellet size for varying disc speeds

following size composition were used for further tests:

in.	%	in.	%
$\frac{1}{2}$ – $\frac{3}{8}$	25	$\frac{1}{8}$ – $\frac{1}{16}$	12·5
$\frac{3}{8}$ – $\frac{1}{4}$	25	– $\frac{1}{16}$	12·5
$\frac{1}{4}$ – $\frac{1}{8}$	25		

Although the frictional force between this material and the disc is not the same as during actual pelletizing it was considered that the figures obtained using these cement-hardened pellets would give a good indication of the effect of disc speed and angle upon pellet distribution. Unfortunately these cement-hardened pellets were too brittle to withstand prolonged treatment in the disc and at the end of the tests the material contained over 40% at $\frac{1}{16}$ in. The variables examined were disc angle and speed and the results are shown in Figs. 6 and 7. In Fig. 6*a* the percentage unpelletized material (for prepelletizing for sintering this is considered to be – $\frac{1}{8}$ in.) is plotted against the distance from the edge of the disc for three different disc speeds, the disc angle remaining constant at 55° to the horizontal. The results for speeds of 19 and 24 rev/min form well defined curves but there is some scatter in the results obtained at a disc speed of 28 rev/min. The high concentration of – $\frac{1}{8}$-in. material observed at the centre may be due to extra fine material being forced down the edge from the scraper at this high speed. However, in view of the trend established for the other two speeds the best curve compatible with this trend was drawn. Figure 6*b* compiled from Fig. 6*a* shows the relationship between disc speed and – $\frac{1}{8}$ in. fracture at the centre of the disc. These results indicate that consistent

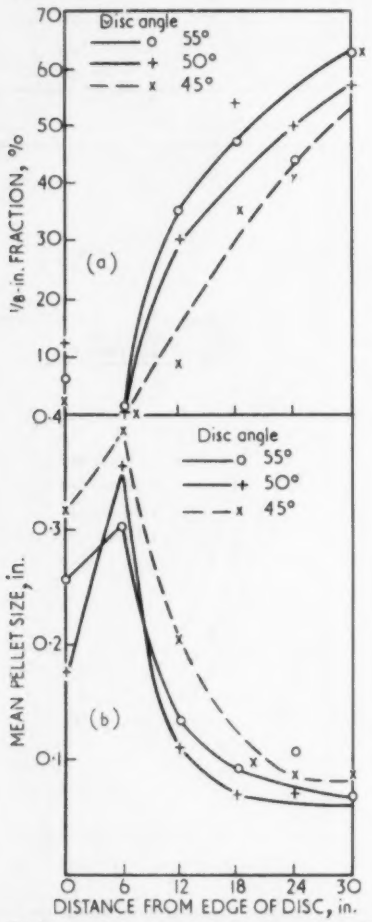


Fig. 7—Sydvaranger (cement-hardened) pellets, (*a*) relationship between disc angle and distribution of – $\frac{1}{8}$-in. fraction, (*b*) distribution of pellet size for varying disc angles

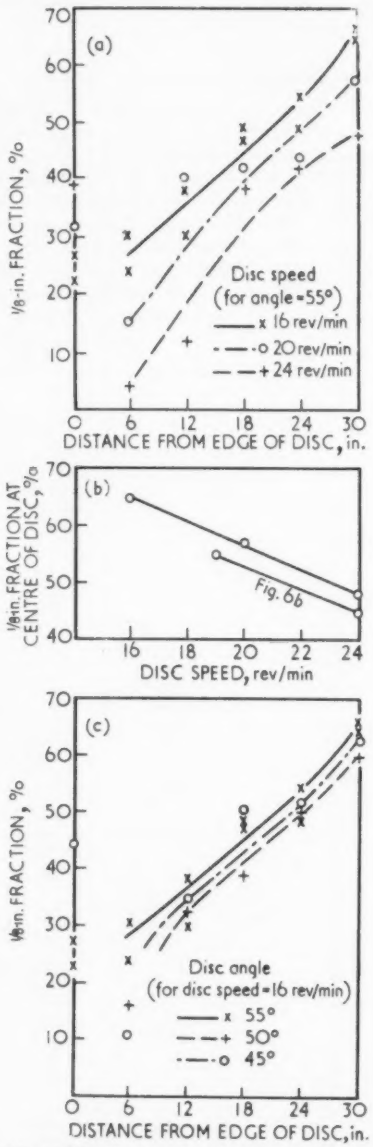


Fig. 8—Lincs–Northants ore, (*a*) relationship between disc speed and distribution of – $\frac{1}{8}$-in. fraction, (*b*) disc speed and concentration of – $\frac{1}{8}$-in. fraction at centre of disc, (*c*) disc angle and distribution of – $\frac{1}{8}$-in. fraction

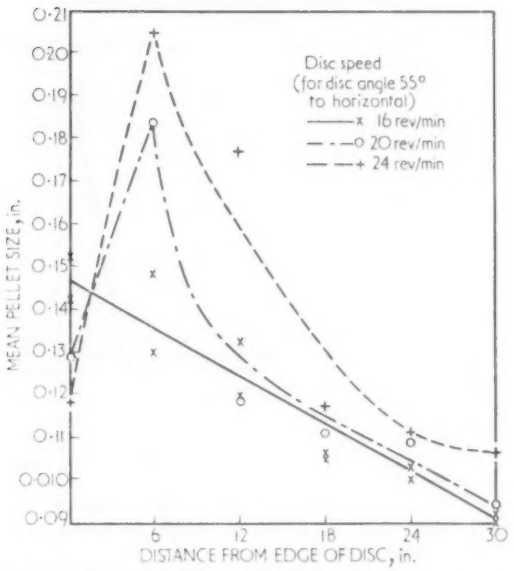


Fig. 9—Dependence of pellet size distribution upon disc speed, Lincs–Northants ore

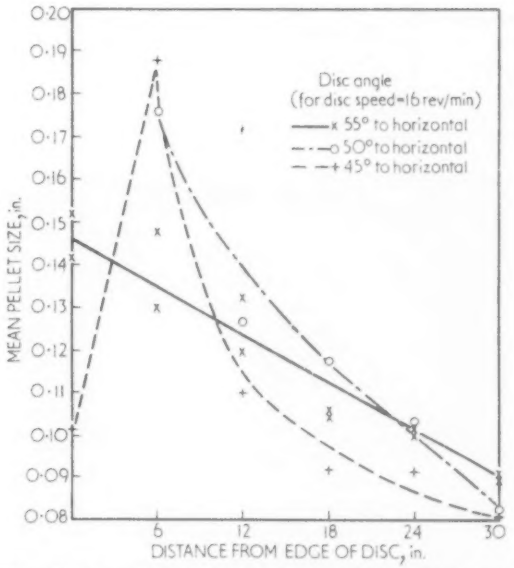

Disc angle
(for disc speed=16 rev/min)
x 55° to horizontal
o 50° to horizontal
+ 45° to horizontal
MEAN PELLET SIZE, in.
DISTANCE FROM EDGE OF DISC, in.

Fig. 10—Dependence of pellet size distribution upon disc angle, Lincs–Northants ore

with some of the material being carried to the top of the disc the percentage of unpelletized material at the centre of the disc decreased with increasing disc speed. These results indicate that position 6 of Fig. 4*a* is the best position to make water addition to the pelletizer and that this is best made when the disc is operating at low speeds. Figure 6*c* shows the distribution of mean particle size across the disc for differing disc speeds, the disc angle remaining constant at 55° to the horizontal. Results showing the effect of disc angle upon pellet distribution for a fixed disc speed of 20 rev/min are shown in Fig. 7. While it would appear that better size segregation occurs at steeper angles no firm conclusion can be drawn from this test because of the unknown effect of pellet breakdown.

Distribution with Lincs–Northants fines

Since a stable system for comparison could not be established within the pelletizer owing to changes in pellet size during experiments, it was necessary to modify the experimental techniques. Lincs and Northants fines premoistened to the correct water content for pelletizing were selected for further experiments since this removed the effect of water addition. A 100 lb of a 2 : 1 Lincs–Northants fines mix was loaded on to the conveyor belt which feeds the disc pelletizer. The disc was set in motion and the material fed into the disc in 20 s; the mixture was pelletized for a further 85 s and samples were taken across the disc during the following 45 s. This procedure was repeated operating the disc at different angles and speeds and the resultant samples sieved on a $\frac{3}{8}$-, $\frac{1}{4}$-, $\frac{1}{8}$-, and $\frac{1}{16}$-in. screen. The $-\frac{1}{8}$-in. fraction and pellet size distribution across the disc was then calculated and the results are shown in Figs. 8, 9, and 10. Figure 8*a* shows the distribution of $-\frac{1}{8}$-in. material across the disc, Fig. 8*b* relating the dependence of the concentration of undersize material at the centre of the disc upon disc speed. This confirms the curve obtained in Fig. 6*b*. It is interesting to note that these two curves have the same slope but different magnitude for the two materials. Figure 8*a* illustrates the start of vortex formation as the disc speed is increased. At disc speeds of 20 and 24 rev/min the $-\frac{1}{8}$-in. fraction ceases to be a minimum at the edge where material would be thrown off, a circulation of larger pellets starting about 6 in. from the disc edge. This is further illustrated in Fig. 9 by the position of the maximum pellet size. Figures 8*c* and 10 show similar results for variation of disc angle. It is clear from these results that decreasing the disc angle increases vortex formation.

POWER REQUIREMENTS

It is interesting to contemplate the dependence of power requirement upon disc diameter for, although this is governed to a considerable extent by manufacturer's design, an estimate of the power required by larger discs would be useful when considering the economics of pelletizing.

During experiments involving Sydvaranger cement-hardened pellets in which the disc was operated at 55° to the horizontal, a note was made of the power input to the pelletizer. The power requirement for the disc operating at various speeds both empty and containing 100 lb of pellets is shown in curves 1 and 2 of Fig. 11. Curve 3 is the difference between curves 1 and 2. For a disc speed of 32 rev/min all the pellets were being carried to the top of the disc and then being diverted by the scraper to the bottom. The power required to lift the pellets only at this speed is, from curve 3, 0·4 h p, assuming a power factor of 0·8. The horsepower required to lift 100 lb of material 32 times/min through a height of 5 sin 55° ft is also 0·40. The agreement between these two results

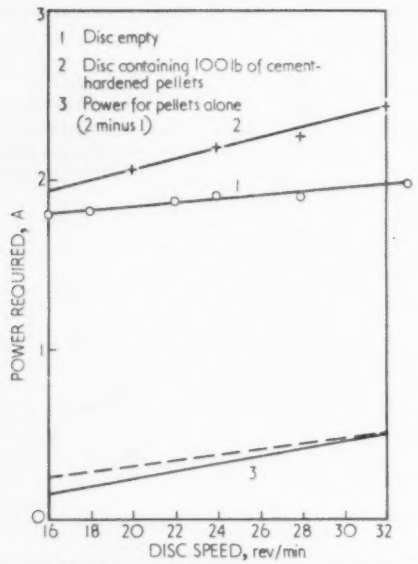

1 Disc empty
2 Disc containing 100 lb of cement-hardened pellets
3 Power for pellets alone (2 minus 1)
POWER REQUIRED, A
DISC SPEED, rev/min
16 18 20 22 24 26 28 30 32
0 1 2 3

Fig. 11—Relationship between power required and disc speed

indicates that this may well be a valid basis for subsequent calculations of power requirement. The broken line in curve 3 with a slope of 0·5 represents the power which would be required to carry all the material to the top at these speeds if frictional forces were sufficient to do so. The ratio of the height of these curves at any point gives, for this case, an indication of the height an average pellet is carried up the disc at these speeds.

The power required by disc pelletizers of up to 15 ft dia. has been calculated. Assuming that a 15-ft dia. disc would have a lip size of 18–20 in. it has been shown that operating at an angle of 50° to the horizontal and using material of bulk density 120 lb/ft³ a useful guide to the power requirement is given by the expression h p = 0·08 $D^{2·25}$ where D is disc diameter, ft: this curve is shown in Fig. 12.

ENERGY UTILIZATION

The size of pellet formed is partially dependent upon the number of revolutions which the material undergoes during its time in the disc, and it is interesting to consider whether this could be applied to give some function of disc performance.

No designed experiments have been carried out to relate the work done on the material and the subsequent pellet size, but there is sufficient information available to make a good assessment of this relationship for a mixture of Lincs and Northants fines. Table V shows the relationship between disc angle and mean pellet size for Lincs and Northants fines at a throughput rate of 2 tons/h. The amount of Sydvaranger concentrates contained in the disc when operating under various conditions is known and from the bulk densities of both materials the amount of Lincs and Northants fines can then be calculated; in this way the residence time and work done per lb of material has been determined.

When operating with the blade scraper in the

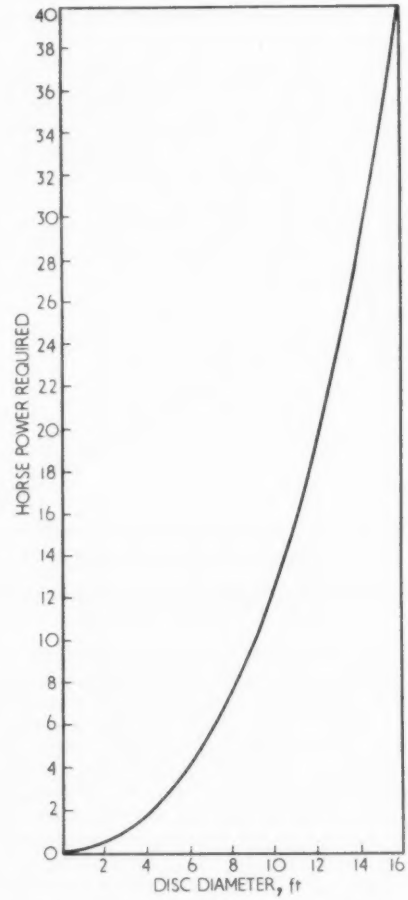


Fig. 12—Relationship between power requirement and disc diameter

position shown in Fig. 1 the work done per lb of material on the material in the disc is roughly equal to $SD\sin\theta\, t$ where S is disc speed rev/min, D is disc diameter ft, θ is angle of disc to horizontal, and t is residence time, min. The dependence of mean pellet size upon work done for the position of the scraper is shown in curve 1 of Fig. 13. Further experiments have been carried out operating a disc without a scraper and the work done has been determined experimentally by noting the power input to the disc during the experiment and subtracting from this the power input when operating the disc empty. Pellet size variations were in these experiments largely obtained by increasing disc throughput. The energy/pellet-size relationship for disc operation without a scraper is shown in curve 2 of Fig. 13. The linear relationship observed suggests that the slope of this line, that is the work done per unit increase in pellet size, may be a measure first of the degree to which materials are amenable to pelletizing and second of the efficiency of the pelletizer for that particular method of operation. The efficiency of the disc when operating without a scraper cannot be regarded as

TABLE V

Relationship between disc angle and mean pellet size

Disc angle, °	Disc speed rev/min	Mean pellet size, in.	Calc. work done
45	24	0·23	204
50	24	0·21	172
55	24	0·16	118
55	20	0·16	134
55	*28	0·18	137
55	*32	0·20	156
		0·05	unpelletized

* For these disc speeds the amount of material in the disc is assumed to be the same as that for a speed of 24 rev/min

100% since other factors such as lip size must be taken into account; it is probable that differing lip sizes will result in varying utilization of the disc surface. The operation of the disc with the scraper in the position shown in Fig. 1 requires considerably more power than that required for operating without a scraper, since in this former case power is lost through the material striking the scraper, and furthermore this exerts a drag on the disc surface. It would appear from energy considerations that a scraper is undesirable, and should therefore be designed to give the minimum resistance to material flow; experiments with a knife-blade scraper close to the disc in the 'six o'clock' position on the disc surface have been unsuccessful owing to an additional flow pattern being created and buckling the scraper. Further experimentation, therefore, suggested that a half-round scraper should be used flat on the surface so that the material tends to roll over it; this has been incorporated in the plant installation of the pelletizer and is the most successful to date.

Experiments to determine pelletizability by rolling moistened pellets down inclines of ore and noting the loss in energy and gain in pellet size have yielded erratic results. It is interesting to note, however, that the energy/pellet-size curves obtained from these tests have a considerably lower slope than curve 2 of Fig. 13.

DISC SHAPE

The effect of disc shape upon disc output and size segregation was investigated in 9-in. dia. wooden models; these are shown in Fig. 14. Tests with an inclined hemispherical bowl were unsuccessful and further work was then concentrated on an ordinary disc, a stepped disc, and a truncated cone. Size segregation was best with the stepped disc and this might well prove suitable for pelletizing materials

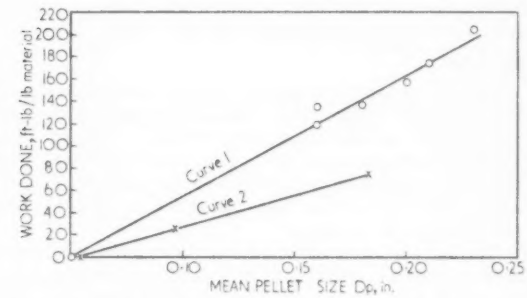


Fig. 13—Relationship between mean pellet size and work done, Lincs–Northants ore

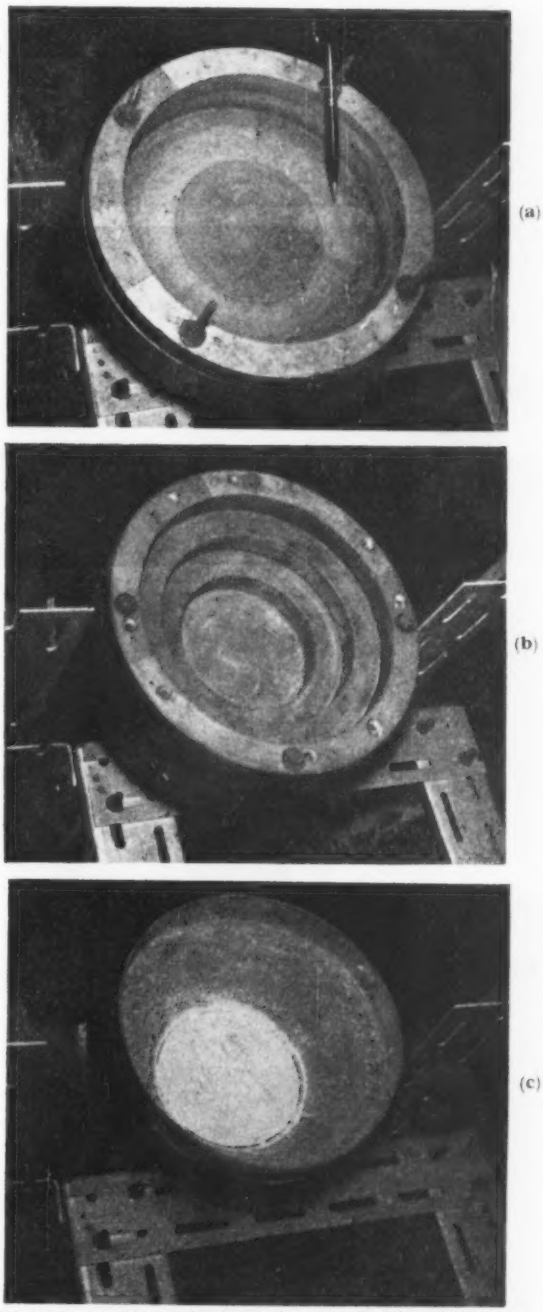
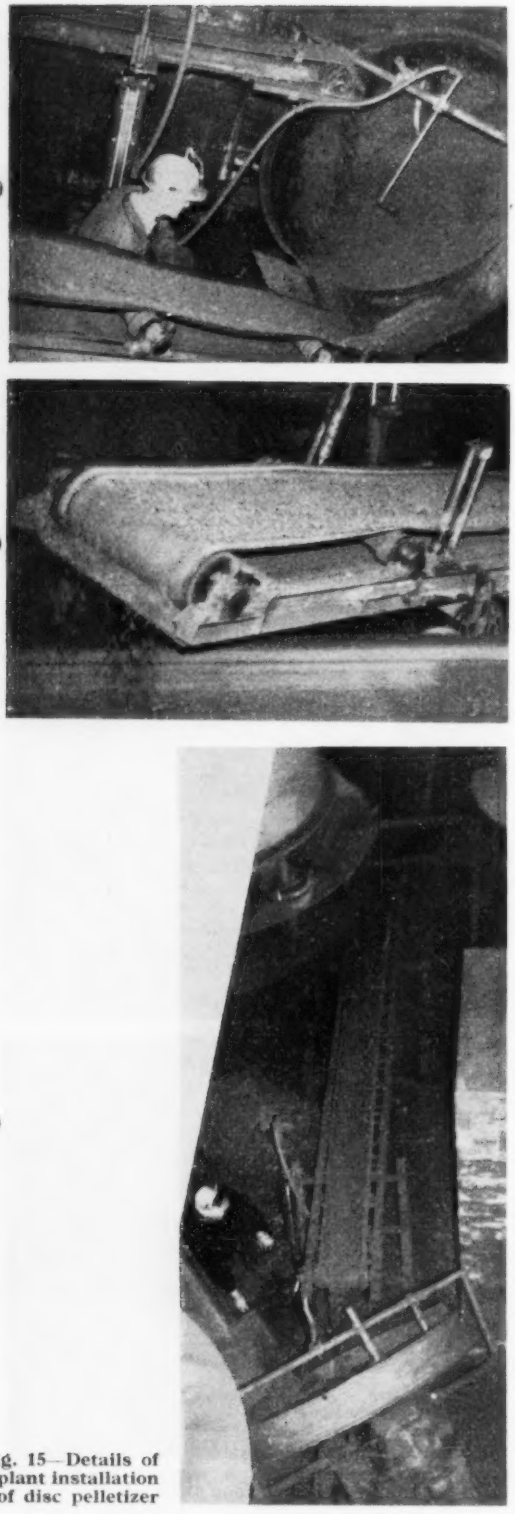


Fig. 14—(*a*) Disc pelletizer, (*b*) stepped disc pelletizer, (*c*) truncated cone pelletizer



(a)

(b)

(c)

Fig. 15—Details of plant installation of disc pelletizer

TABLE VI

Pellet breakdown at belt change stations

Size grade	Pellets	After one drop	Pellets	After one drop	Pellets	After one drop	Pellets	After one drop	After two drops
Sydvaranger									
$-\frac{1}{4}$	25	...	...		...	...			
$-\frac{3}{8}+\frac{1}{4}$	75	28	42	12	...	...			
$-\frac{1}{4}+\frac{3}{16}$	...	4	38	12	4	7			
$-\frac{3}{16}+\frac{1}{8}$	...	13	13	12	48	14			
$-\frac{1}{8}+\frac{1}{16}$	...	18	0	12	36	29	48	40	20
$+\frac{1}{16}-\frac{1}{8}$	...	37	8	52	12	50	35	33	24
$-\frac{1}{16}$							17	27	56
Lincs-Northants									
$+\frac{1}{4}$							2	3	2
$-\frac{1}{4}+\frac{3}{16}$							4	6	6
$-\frac{3}{16}+\frac{1}{8}$							39	40	44
$-\frac{1}{8}+\frac{1}{16}$							49	45	41
$-\frac{1}{16}$							4	6	7
Labrador									
$+\frac{1}{4}$							16	23	27
$-\frac{1}{4}+\frac{1}{16}$							72	69	67
$-\frac{1}{16}$							12	8	13

requiring very fine control. Disc output was lower with this disc in proportion to the reduction in area of the pelletizing zone, i.e. the central disc. The truncated cone gave similar size segregation and output to an ordinary disc of the same size, but since it contains considerably more material it would have a higher power consumption.

PLANT INSTALLATION

In April 1958 the opportunity to install a disc on an operating sinter plant became available and the disc was installed at the West Hartlepool works of the South Durham Steel and Iron Co. In this installation, shown in Fig. 15, the material for use in the disc is fed from a reserve coke bin via a feeder table and conveyor to the disc and, after pelletizing, the material is conveyed by a second belt to the main ore belt feeding the sinter plant. Material input rate to the disc can be measured by taking tray weights, and water additions are measured by a rotameter. The installation is such that the reserve coke bunker can be fed with material brought into the plant either by road or rail, but work has concentrated upon those ores being used in the sinter plant.

Results

First runs were carried out using Northants fines; this material is admirably suitable for pelletizing and was easily pelletized at 5–6 tons/h. During this period the ore screened at $-\frac{3}{4}$ in. was rather wet and no water additions were required for pelletizing and as a result of this the fines tended to adhere to the large lumps of material.

The next material studied was Sydvaranger concentrates. After some initial practice in controlling the material and water feed rates this material was pelletized at about 4 tons/h. Considerable difficulty was encountered in producing pellets of a size suitable

TABLE VII

6½-h run with Labrador fines at average throughput rate of 6·7 tons/h

Size grading	Feed material	Pelletized feed	After one drop	After two drops (i.e. into bunker)	Bunker exit	Feed into mixer (including ore + r. fines)	Feed from mixer
+ ½ in.	16	18	25	24	20	9	9
½ − ⅜ in.	9	18	13	12	14	7	6
⅜ − ¼ in.	16	22	16	19	19	16	15
¼ − ⅛ in.	17	31	27	31	17	19	21
⅛ − 1/16 in.	14	9	13	8	11	15	16
1/16 − 1/32 in.	18	1	3	2	13	17	17
− 1/32 in.	10	1	3	3	6	17	17

for sintering; the pellets were almost invariably too large, the usual size range being about ⅜–½ in. It was noticed during this period that the Sydvaranger pellets deteriorated considerably during subsequent passage through the system and it was decided at this stage to determine to what extent pellets would survive normal handling systems and to give some indication of where, in a proposed plant, discs might be conveniently situated. The plant layout at South Durham is such that the ore is fed from feeder tables on to a conveyor belt. The ore stream then passes two belt change stations where it undergoes two 6–8-ft drops. The material then falls into the mixed ore bunker where with the bunker half-full the material drops about 20 ft. The first investigation concerned the breakdown of Sydvaranger pellets; the large pellets produced by continuous operation of the disc suffered considerable deterioration in size and tests were then made to determine whether, if smaller pellets could be made, they would survive change stations. The results of these tests are shown in Table VII and these indicate that regardless of their size, Sydvaranger pellets would not be strong enough to survive 6- to 8-ft drops and that a pelletizer operating on this material would need to be interposed, at the earliest, immediately before the mixer. Further tests of this nature were then carried out with pellets made from Labrador fines and a mixture of Lincolnshire and Northamptonshire fines; in both these cases the pellets were made in batches. The results of these tests are also shown in Table VI. These results show that pellets made from these two materials are capable of survival at change stations. A further test was then carried out to determine if pellets made during a period of continuous operation were capable of withstanding handling at change stations and passage through the mixed-ore storage

TABLE VIII

Output rating tests with Labrador fines

Size grading	Unpelletized	2 tons/h	Unpelletized	4 tons/h	Unpelletized	6 tons/h	Unpelletized	8 tons/h
Half-round scraper Series 1								
+ ½ in.	32	28	30	19	18	13	32	17
½ − ⅜ in.	12	18	14	11	17	13	17	18
⅜ − ¼ in.	21	33	16	24	14	21	13	20
¼ − ⅛ in.	12	19	12	39	14	34	11	20
⅛ − 1/16 in.	10	2	12	7	13	17	8	20
1/16 − 1/32 in.	10	0	16	0	22	2	19	5
− 1/32 in.	3	0	0	0	2	0	0	0
D_p	0·139	0·317	0·151	0·241	0·110	0·191	0·147	0·179
Series 2								
+ ½ in.	21	21	19	20	22	20	15	14
½ − ⅜ in.	11	14	10	14	11	10	10	14
⅜ − ¼ in.	14	29	17	32	15	23	13	16
¼ − ⅛ in.	13	27	15	26	13	27	14	27
⅛ − 1/16 in.	11	6	10	5	10	12	13	20
1/16 − 1/32 in.	11	2	12	1	10	4	15	5
− 1/32 in.	19	1	17	1	19	4	20	4
D_p	0·059	0·213	0·062	0·225	0·059	0·119	0·054	0·112
Original blade scraper								
+ ½ in.	15	20	12	13	17	10	18	13
½ − ⅜ in.	16	14	12	9	8	9	10	8
⅜ − ¼ in.	15	44	15	25	16	28	18	25
¼ − ⅛ in.	16	20	12	41	13	37	13	30
⅛ − 1/16 in.	15	2	12	8	13	11	12	16
1/16 − 1/32 in.	15	0	13	2	15	3	12	4
− 1/32 in.	7	0	24	2	18	2	18	4
D_p	0·090	0·302	0·048	0·169	0·057	0·159	0·059	0·128

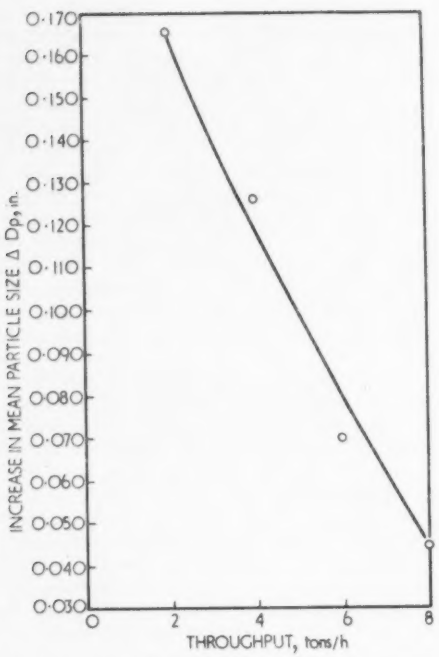


Fig. 16—Relationship between increase in mean particle size and disc throughput, Labrador fines

bunker. The results of this test, which lasted 6½ h, are shown in Table VII. These results indicate that there is only small breakdown as far as the mixed-ore bunker but, as a result of dropping into the bunker and storage, considerable deterioration occurred.

Tests were carried out to determine the output rating for Labrador fines with both the original blade scraper and the half-round scraper; the results of these tests are shown in Table VIII. Output ratings are of a similar order for both scrapers, but it was decided to adopt the half-round scraper because of the lower power input required. Figure 16 shows the disc throughput plotted against the average increase in pellet size for series 1 and 2. The output rating for the disc will in practice be determined by the particle size of the input material.

Single tests were carried out with pyrites residues and mixed home ore fines; pyrites residues could not, in fact, be satisfactorily pelletized, but the results for mixed home ore fines are shown in Table IX. In the main the extended runs at West Hartlepool have not shown the anticipated advantages of continuous operation that had been hoped. Only in the case of easy materials with clay-like constituents did it prove possible to make small strong pellets at reasonable throughput. This would appear a serious disadvantage in dealing with the wide variety of ores processed at most UK sinter plants.

CONCLUSIONS

Pilot-plant scale experiments with a 2 : 1 mixture of Lincs and Northants fines show that considerable improvements in average sintering permeability can be achieved by prepelletizing. Increases in permeability

TABLE IX

Output rating test with mixed home ore fines

Size grading	Unpelletized	2 tons/h	Unpelletized	4 tons/h	Unpelletized	6 tons/h
+ ½ in.	3	4	3	2	7	7
− ½ + ⅜ in.	3	8	3	6	7	7
− ⅜ + ¼ in.	23	49	19	25	21	43
− ¼ + ⅛ in.	27	34	22	45	21	33
− ⅛ in.	44	5	53	22	44	7
D_p	0·107	0·226	0·096	0·145	0·11	0·217

of from 55% to 38% have been obtained at disc throughputs of from 1 to 6 tons/h.

Experiments with Cleveland mix indicate that some improvement in average sintering permeability can be effected by aggregating the ores in a disc pelletizer. Since similar improvements have been made by treating the raw mix in a small cement mixer it is likely that this effect could be brought about by increased drum mixing. Considerable reduction in sintering time can be achieved by pelletizing only the − ⅛-in. fraction of the raw ores though this is unlikely to be practicable on the full scale.

It has been shown that prepelletizing can be used to introduce to the sinter mix materials, in the form of pellets, previously regarded as deleterious because of their small particle size. Up to 10% flash-roasted pyrites pellets have been introduced to the Cleveland mix without increase in sintering time.

Investigation of pellet distribution within the disc has shown that for best formation and classification the disc should be operated at the lowest speed consistent with lifting a reasonable proportion of material to the top of the disc; the establishment of an unused vortex is to be avoided. The position of water introduction just below the scraper at the centre of the disc ensures that the water has the maximum chance of wetting unpelletized material.

The installation of a disc pelletizer to treat the ore stream from a sinter plant feeder table has shown that the disc can be operated to produce pellets continuously. From sticky or clay-like ores high throughputs of up to 8 tons/h for a 5-ft disc have been obtained. Pellets from sticky or clay-like ores are capable of standing 6- to 8-ft drops at belt change stations but disintegrate considerably during bunkering and this evidence suggests that the pellets should be introduced to the mix just prior to the mixer.

Pellets made from very fine materials, which pelletize readily, are generally too large for sintering and are not sufficiently strong to withstand drops at belt change stations. These materials might well be more amenable to treatment when mixed with other ores before pelletizing. It has generally been necessary for an operator to be present at all times to adjust the water control due to fluctuations in the material flow from the feeder table.

The advantages to be gained by prepelletizing ore mixes before sintering have been shown. The use of a disc pelletizer throughout the tests, however, precludes comparison of disc and drum pelletizing.

ACKNOWLEDGMENTS

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Recent developments in oxygen steelmaking in North America

By J. M. Gaines

SYNOPSIS

The paper describes briefly the most important recent trends and advances that characterize the application of oxygen in making iron and steel in North America. The most immediately significant applications are: (*a*) the evolution of a workable practice for open-hearth heats using oxygen through the roof; (*b*) the growth of the basic oxygen steel process; (*c*) the use of oxygen in electric-arc furnaces; and (*d*) a growing concern over the potentialities of oxygen enrichment to produce more hot metal from existing blast-furnaces. The subjects of hot metal pretreatment and direct reduction of ore are also considered in so far as oxygen is involved. 1702

THERE IS hardly a phase of large-scale steel processing in which oxygen is not involved in some way. In fact, the growth of oxygen usage is, to a degree, self-stimulating. For example, its chief use in steelmaking is to oxidize carbon and silicon from steelmaking charges, thereby generating useful heat. The success of this application immediately creates a demand for additional hot metal and directs attention to oxygen as a means of increasing blast-furnace output with minimum capital requirements.

The author makes no claim to be an expert in the many and varied subjects covered in the paper. His viewpoint is that of one of the large suppliers of oxygen to the steel producers, who is interested to observe and analyse trends so as to be able to provide whatever may be needed at the proper time.

THE OXYGEN INDUSTRY

In the USA there are some 375 oxygen plants, with 26 or more scheduled. The total annual output of these is about 140 000 000 000 ft³ (about 5·8 million tons).[1] About half of this goes to the steel industry, mainly for steelmaking and for scarfing. A dramatic illustration of this growth is afforded by the 'oxy-ingot' ratio, obtained by dividing the delivered volume of gas by the ingot production each month, which is shown in Fig. 1. (This applies only to the customers of the author's company, but it probably represents fairly well the industry trend. It includes oxygen used for scarfing and miscellaneous steel mill purposes.) The rapid rise since mid-1957 is strongly in evidence, coinciding with the expansion of the 'on-site' type of oxygen supply and the growing use of oxygen in open-hearth operations. The most recent advance in this area is the new Monongahela River oxygen plant, announced last year. This will be owned and operated by Linde Company, and will supply 1 000 tons/day to a pipeline connecting four large mills of the United States Steel Corporation along the river above Pittsburgh. This plant, which will furnish high-purity gas at 250 lb/in² pressure, is scheduled to be in operation early next year.

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THE BLAST-FURNACE

Two plants regularly enrich the air blast, one for basic iron and the other for ferromanganese. At the Weirton Steel Company, four basic furnaces receive a total of 500 tons of oxygen daily.[2] This represents an average addition of 1·8% oxygen to the air. Up to 4% has been used, giving some 19% increase in iron output. Adding moisture to control hearth temperature in relation to oxygen content and blast temperature is found to be both needful and beneficial. Increase in moisture by 5·0 grains per cubic foot is equivalent thermally to 1·0% O_2 or a rise of 150° F in the blast temperature. A 'modest' decrease in coke rate is reported.

Two ferro-alloy furnaces at Duquesne, Pennsylvania (United States Steel) have received 430 tons of 95% O_2 daily since May, 1957. During the first year, a maximum of 26·5% oxygen in the blast was used. This increased the output, from the normal of 686 tons/day for both furnaces, by 30%. Stapleton[3] has given detailed data for the smaller of the two, showing that coke consumption declined by nearly 500 lb/ton, from 3 765 to 3 292 lb/ton. As would be expected, slag volume also decreased from 1 879 to 1 629 lb. At the same time the manganese content of the slag dropped from 7·96% to 7·45%, corresponding to a net gain for the furnace of 20 lb Mn per ton of product. On the basis of these favourable results it can safely be predicted that a blast of 30% oxygen would show even more striking economy and further production gains. It has been estimated that top-gas temperature would remain satisfactorily high, even at 38% oxygen.

In both these plants, it is evident that more oxygen could be used than is now available. The maximum level of enrichment using steam and oxygen in existing furnaces may be quite high.

On the part of operators there is great interest in test enrichment. Oxygen for test purposes can be

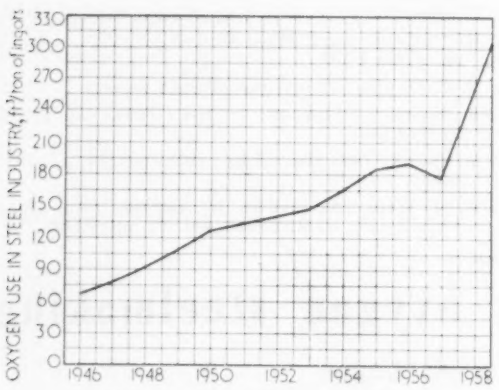


Fig. 1—Oxygen usage, 1946–1958

obtained either from tank-car shipments of liquid or by diverting to the blast-furnace the output of an 'on-site' oxygen producer. One such test has been completed and reported by the Jones and Laughlin Steel Corporation.[4] Here the highest enrichment used was 2·5%, with 7 grains of moisture. Production increased 11·5% while coke consumption diminished by 117 lb/ton. This test occupied several months, during which time several levels of enrichment were used. Among the conclusions may be cited the finding that no difficulty was experienced when the enrichment level was changed rapidly, provided that proper adjustment was made at the same time in the moisture content and temperature of the blast.

A two-month investigation of enrichment was carried out by another operator. Blast oxygen was increased to a maximum of 23·5%. With nearly constant total wind and blast temperature, a production gain of 8·5% resulted. The coke rate increased by 18 lb/ton. Moisture in the blast was raised from 14 to 20 grains/ft³ during the enrichment period. Significant was a drop in flue dust from 208 to 69 lb. On air the furnace made 1 533 tons/day with 1 384 lb of coke per ton. In this experimental campaign it was also demonstrated that oxygen can be used intermittently at will if other changes were made concurrently.

Active consideration of testing is under way at four or five additional plants, looking towards completion in 1959. From the scattered data so far at hand, it appears that the rough rule-of-thumb, which states that a ton of supplementary oxygen added to the wind yields an additional ton of iron, is safe at least up to a moderate enrichment. Questions that remain to be answered by separate trials include:

(*a*) Proper moisture and temperature level for a given oxygen input and for each type of burden. In general it seems that burdens that can use high blast temperatures require less moisture for smooth working with oxygen.

(*b*) Evaluation of top-gas fuel credit. With enrichment the heating value may exceed 100 Btu/ft³. Because of higher driving rates and lower stove heat requirements, there may be as much as 0·5–1·0 million Btu/ton more available top-gas heat than with air. If some coke saving is realized, this excess will diminish. The credit for quantity and quality of top-gas heat units is potentially important in the economic evaluation of enrichment.

To provide a basis for comparison and for prediction of the effects of enrichment, the laboratories of the author's company have been working for several years on the quantitative calculation of the blast-furnace process. A method has been worked on in which the calculation is performed by electronic computation. In this, detailed heat and material balances are used, together with equations relating to heat-transfer rates and to the ratio of direct to indirect reduction. If a full set of data pertaining to a particular furnace and burden are available, it becomes possible to compute the effect of a change, such as in moisture or oxygen content, determining new values for the other variables such as coke rate, top temperature, slag volume, and driving rate. This has been applied to several furnaces, including one with enriched blast; the agreement with actual results has been gratifying and encouraging. More good data are needed to refine this method.

A review of current blast-furnace use of oxygen would be incomplete without reference to the subject of supplementary fuels. The possibility of reducing coke usage and of obtaining better utilization of oxygen is attractive. The author is not aware of any experimental work along these lines carried out in the USA, although there is considerable planning activity in this direction. Much interest attaches to results of tests being carried out in Europe.

It should be pointed out, as a final comment on the blast-furnace, that oxygen is only one of the ways of increasing production. Higher top pressure and the use of beneficiated burdens are two other methods that might be mentioned. It appears that oxygen enrichment will be at least as beneficial with prepared burdens as with natural ores.

OXYGEN PRETREATMENT OF HOT METAL

This is usually understood to refer to oxygen injection into blast-furnace iron to remove silicon (and sometimes some of the carbon). Productivity increases predicted on theoretical grounds for the use of 'treated metal' run as high as 30% in open-hearth and 50% in arc furnaces,[5] assuming that all the silicon and about half the carbon is removed. Despite this inducement, there is almost no use of oxygen pretreatment, for the following reasons:

(1) The special conditions that have lead to its widespread use in European works do not generally exist in the USA, where there is no need to beneficiate the slag as a worthwhile by-product, or to reduce tendencies to slopping and spitting in the basic Bessemer converter.

(2) The investment required for an adequate treatment (including fume control) is appreciable.

(3) In open-hearth practice the roof jet, with a clean slag flush, is an effective way of desiliconizing *in situ*. Hence the amount of pretreatment is substantially nil, apart from conventional duplex operations.

There are special situations, however, where pretreatment with oxygen is of interest and, in consequence, efforts are continuing to devise a good process. Among such situations may be cited the use of hot metal in arc furnaces; here removal of silicon (plus some carbon) gives worthwhile reduction in slag volume and speeds up refining. Among the suggested methods for effecting the operation are lancing in the ladle, pouring through a 'shot tower,'[6] or treating in

the blast-furnace runner in a manner resembling the IRSID process.[7]

BASIC OPEN-HEARTH FURNACES

The use of oxygen to accelerate combustion of liquid fuels (heavy fuel oil, tar, or pitch) continues to be practised in numerous hot- and cold-metal shops. Almost universally, the gas is introduced as a high-velocity stream directly below the atomized fuel, the amount varying from 200 to about 500 ft³/ton. This results in (*a*) increasing the permissible firing rate by 10–25%, (*b*) providing maximum temperature and oxidizing power in the lower portion of the flame, which is in contact with scrap and bath, and (*c*) avoiding extreme temperatures in contact with the refractories. It is difficult to assign a value to this practice in terms of increased production or fuel savings (both of which occur), because it is almost always associated with use of direct bath injection of oxygen. Flame enrichment is most effective in furnaces that are close to their maximum firing rates, and especially where checker volume is small in relation to heat size. It is probable that, in the favourable cases, production increases of 10–15% and fuel savings of 5–10% can be attributed to this type of oxygen use.

In cold-metal shops in particular, several plants are using auxiliary burners located in the corners of the furnace. These are fed with gas (natural or coke oven) and oxygen and are operated only during meltdown in order to get the scrap knocked down more quickly.

Most melting shops use oxygen for direct oxidation of the bath for removing carbon in the lower ranges, for starting bath action, raising temperature, or assisting in shaping up slags. These operations are in routine use and warrant no special comment. The lance pipe is commonly used and the oxygen rarely exceeds 100 ft³/ton.

Most spectacular is the general acceptance of the vertically suspended roof jet, the use of which by the United States Steel Corporation has been described by Pearson.[8] Although this company is far advanced in the systematic use of the principle in its application to an entire shop, others are in various stages of testing, regularizing, and extending the practice. It is estimated that 75–100 furnaces in 25–30 mills are now equipped with roof jets. A recent announcement[9] by the Weirton Steel Company revealed a single test heat of 535 tons in which a charge of 86% blown metal and scrap was made at a rate better than 100 tons/h (tap-to-tap) with about 900 ft³ of oxygen per ton (700 ft³ were fed to three jets and 200 ft³ were used in the burners).

In more usual roof-jet practice, using hot metal, oxygen substitutes for some of the normal ore charge and the heat of direct oxidation of the metalloids is absorbed by melting scrap. Oxygen rates of 100–250 ft³/h per ton are used from the time of hot-metal addition to the end of refining. As many as three jets are employed in very large furnaces; these operate continuously without regard to the reversals of the flame, for periods of 3–7 h, depending on the size of the heat and the hot-metal ratio.

Some idea of the speed of refining possible is given by Fig. 2, which is a composite of representative

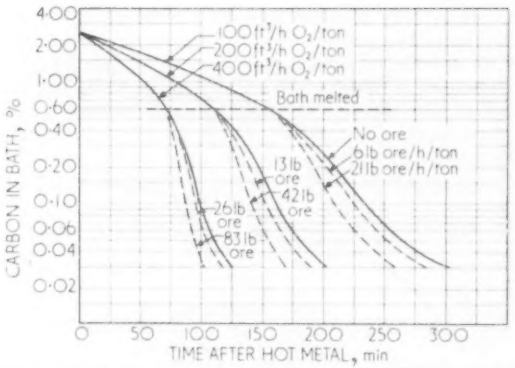


Fig. 2—Carbon drop versus time for various oxygen flow rates and ore input (60–65% hot metal)

values from several furnaces with 60–65% hot-metal charges.[19] This shows the carbon content at various lengths of time for three different rates of oxygen supply (solid lines). Because the reactions are highly exothermic, fuel rate is usually reduced during the blow; alternatively, ore may be fed to balance partially the heat effect, increase further the refining rate, and enhance yield. This is shown by the broken lines, where O_2 plus ore is indicated. The smaller ore addition shown in each case is sufficient to absorb 20% of the heat of the oxygen reactions; the larger ore quantity is equivalent to 65% of this heat. Several mills are evaluating this procedure; none, so far as the author is aware, has attempted injection of ore with the oxygen, a practice that might reduce the smoke production.

The reduction in fuel during blowing may be total or partial, depending on thermal requirements. Air control is important; the rate of CO evolution from oxygen and ore reactions is high enough to require a substantial quantity of air to utilize the available heat units in burning it to CO_2. Proper conditions can be maintained by use of an oxygen analyser on the waste-gas stream.

With thought to the efficiency of oxygen utilization in the open-hearth furnace, Hodge[10] has analysed the sources and ultimate destiny of oxygen in a typical heat. These computations take into account the need to build up dissolved bath and slag oxygen to satisfy the needs of equilibrium in the system. Figure 3 taken from his paper shows, for example, that at 0·05%C, input of oxygen as injected gas roughly equals that from ore and the atmosphere. The amount reacting with carbon is about one-tenth of the input, illustrating the fallacy of equating bath-carbon drop with the volume of oxygen injected. It also shows the importance of keeping minimum slag volumes when making low-carbon steels. (The curves in Fig. 3 refer to heats with 170 lb of slag per ton.)

The service conditions for the ' business end ' of a roof jet are severe. Particles of slag are projected violently upwards by the boil; at times drops of steel adhere, only to be suddenly consumed by the oxygen atmosphere, resulting in a ' scarfing ' action. At the same time, the jet must function efficiently with respect to oxygen utilization while causing minimum

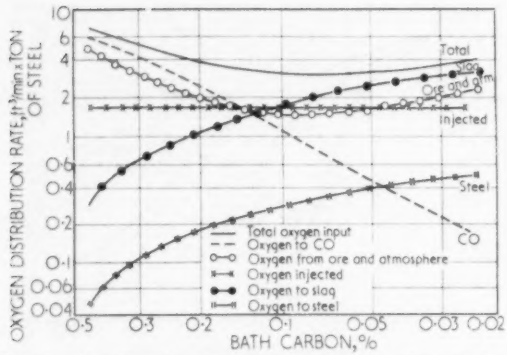


Fig. 3—Distribution of oxygen in an open-hearth heat (basicity 3·0)

splash of slag or metal droplets on to the roof. As a result of several years of experiment in this field, the author's company has developed adequate cooling-passage design and material specifications for long life. Consideration of performance characteristics leads to the use of multi-orifice devices, the openings diverging from the centre-line to cover a greater bath area and minimize splash.

Figure 4*a* illustrates the copper head of one of these devices, before being attached to the steel tubes. The six diverging oxygen ports and the six radial water drillings can be seen. Figure 4*b* is a view of another of the same type after about 700 h of use. The deep erosion of the copper near the oxygen passages is typical. This jet was run at various flow rates from 15 000 to 40 000 ft³/h; it was usually hung 6–12 in. above the slag level.

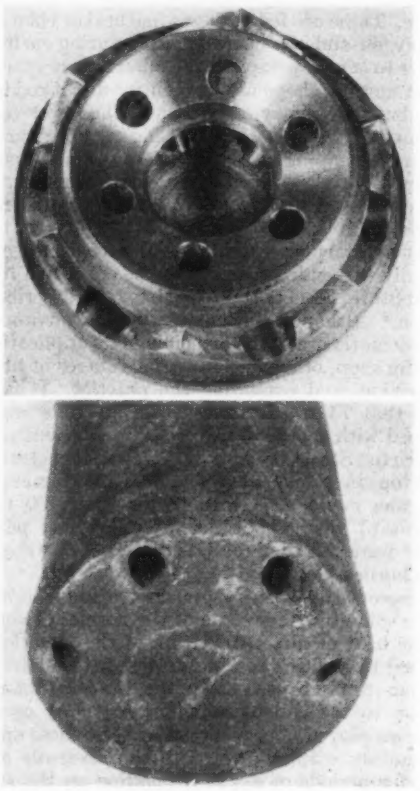
ELECTRIC FURNACES

Because gaseous oxygen is generally cheaper than ore (plus power), it is widely used in finishing electric-furnace heats of a wide range of steels. Injection is accomplished by means of lance pipes or water-cooled jets inserted through the doors. Consumption, which depends on the carbon level, averages about 30 ft³/ton.

Finishing chromium-steel heats, especially the 12–18% grades, warrants special mention. Although oxygen had long been used for this purpose, Healy and Hilty[11] showed that by blowing at very high rates it was possible to raise bath temperature rapidly, with benefits to total oxygen use, elapsed time, and with higher recovery of chromium. Because at higher bath temperatures equilibrium shifts toward lower carbon contents at a given bath chromium content, the melter is able to use additional quantities of chromium scrap and high-carbon charge chromium while reducing his requirement for more costly low-carbon materials. This has been recently elaborated by Hilty *et al.*[12] through the application of linear programming for electronic computation, into a procedure for charging and finishing stainless-steel heats to achieve minimum materials costs. The rapid-blow practice is gradually spreading throughout the industry. Usage of oxygen is 400–500 ft³/ton, with rates as high as 2 000–3 000 ft³/h per ton.

The advent of large-diameter furnaces has presented some problems in melting the scrap around the periphery. It would usually be desirable to melt this at about the same time as that under and near the arcs, rather than to have it fall into the bath, with possibly harmful results, some time later. Oxygen is used to meet this situation, either by playing it directly on the scrap after the latter has reached the ignition temperature, or in combination with gaseous fuel (natural or coke-oven gas). A number of jets or burners are used and are operated until the scrap is substantially melted. Consumption may reach 800 ft³/ton. In some cases a saving in time and power of 12–15% is realized. Frequently the power saving alone more than pays for the oxygen. Similar procedures are useful also on smaller furnaces, especially where transformer capacity limits the melting rate.

There is a growing tendency to use hot metal in arc furnaces in shops that possess both electric furnaces and blast-furnaces. Here, even more than in the open-hearth furnace, injected oxygen is essential to rapid decarburizing. Variations of the roof jet, but inserted through water-cooled openings in the shell, are being investigated. Oxygen consumption ranges up to 350 ft³/ton and hot metal ratios of 25–30% are usual. Occasionally 50% has been used; there are some difficulties with slag volumes in this case, as well as with venting of the gases evolved.



(a)

(b)

Fig. 4—Copper head of multi-orifice oxygen jet: (*a*) before attachment to steel tube; (*b*) after use for 700 h

BASIC OXYGEN PROCESSES

Of the various modifications of this process, the L–D is the only one in use in North America. It appears to be gaining steadily by virtue of its low investment cost, simplicity and cheapness in operation, good product quality, and unexpected flexibility. Six plants now built or building in North America are:[13]

	No. of vessels	*Nominal capacity per vessel, tons*	*Yearly capacity, tons*[15]
Canada			
Dominion Foundries and Steel Company	1	66	800 000
	2	44	
Algoma Steel Corporation	2	66	400 000
USA			
McLouth Steel Corporation	2	80	1 385 000
	3	35	
Jones and Laughlin Steel Corporation	2	65	750 000
Kaiser Steel Corporation	3	65	1 450 000
Acme Steel Company	2	50	450 000
		Total	5 235 000

Several other firms are reported to be in the decision-making stage, and indications are that the use of the process will show a vigorous growth in the next few years. The availability of the proper grade of hot metal in most areas of North America is one reason for the acceptance of the process. The range of iron analyses is: C, 4·0–4·4%; Si, 1·0–1·7%; Mn, 0·5–1·3%; P, 0·10–0·15%; S, 0·03–0·05%. With irons of this type, the amount of scrap that can be used varies from 20% to about 30–32% of the metallic charge. One plant is using regularly, on low-carbon heats, about 12–13% scrap with 5% of sinter. The relation of silicon content to scrap usage has been discussed by McMulkin[14] and analysed from a thermochemical viewpoint by Philbrook.[15] The latter points out that much more scrap could be accommodated if a portion of the heat available in the CO produced could be released and retained in the furnaces. He concludes that with Si at 1·2%, as much as 48% of cold scrap could be used.

Refractory requirements are proving to be modest. The inner replaceable lining is tar-bonded dolomite brick, usually backed by ramming with the same material. Consumption is 15–22 lb/ton, and the life between relinings runs between 175 and 280 heats, with the better figures apparently resulting from longer experience. General practice is to have one or two converters in use while the remaining unit is being relined.

Oxygen usage, based on tons of ingots, depends on hot-metal composition, relative amounts of scrap and oxides in the charge, and the size of the heat. Loughrey[16] reports as low as 1 500 ft³/ton at Jones and Laughlin. Other plants report 1 600–1 850 ft³/ton.

Blowing rates, depending on vessel size and volume filled with liquid charge, range from 3 000 to 6 000 ft³/min. Usually the lance is placed 5–6 ft above the bath, the exact point being selected with a view to minimizing excessive slopping while maintaining good production rates. Nozzle sizes (1–2 in.) are such that the indicated flow of oxygen is always delivered at supersonic velocity. Blowing time is usually 20–28 min, and tap-to-tap intervals 45–60 min. The nominal capacity rating of the vessels is conservative; a '65-ton' unit easily handles 80 tons and is frequently used for more than 90 tons. Two such vessels can apparently maintain better than 80-tons/h production.

The results of operating the two 65-ton vessels at Jones and Laughlin[16] in January, 1959, show:

Number of heats	763
Tons of ingots	62 607
Tons per heat	82·05
Tons per hour (tap-to-tap)	86·8
Blowing time per heat	21·8 min
Oxygen, ft³/ton	1 515
Charge: Scrap	29.74%
hot metal	69·40%
Yield	92·80% of iron units charged

Hot-metal analysis shows the following range: Si, 0·90–1·70%; Mn, 0·40–0·50%; P, 0·125%.

A variety of products are being made by the several users of the process. Although originally regarded as most suitable for low-carbon grades (chiefly sheet and wire), it is proving quite versatile. With rapid analysis of the hot metal (Si content) and accurate metering of the oxygen, it is possible to preset conditions to finish blowing at desired carbon levels up to 1·0%. Among the products being made are seamless tubes, structural steels, rails, ball-bearing steels, and crankshaft steels.

Producers express general satisfaction with quality. The ability of the process to reach low levels of phosphorus, sulphur, and nitrogen is of major importance in securing good properties in deep-drawing sheet, tinplate, and wire for welding or cold-heading.

Representative final analyses from various mills show that good control is possible in respect to:

S	0·015–0·025%
P	0·010–0·015%
N_2	0·002–0·004%

Since the oxygen used is in every case a high-purity product (99·5%), there is no nitrogen problem. In fact, since there is little difference in cost for 99·5% as compared to lower purity, such as 95%, when calculated on *contained* oxygen, and since most mills require 99·5% for cutting and scarfing, there is little inducement to set up a separate purity standard (except for large single-purpose supplies, as for blast-furnaces).

The subject of the economics of this process in comparison with older methods is complicated, especially in view of the productivity increases, largely due to oxygen, that are taking place daily in open-hearth and electric furnace operations. Full discussion of this subject is beyond the scope of this paper; it is interesting, however, that the cost of oxygen is a minor portion of the ingot cost, and can hardly be a determinant in the choice between various new processes, e.g. with oxygen at $15 (£5·35) per ton:

Process	*O_2 used, (ft³/ton)*	*O_2 cost, ($ per ton of ingots)*
Open-hearth with roof jets	600–900	0·38–0·56
Electric furnace*	350–800	0·23–0·50
L–D	1 500–1 800	0·94–1·13

* Assuming hot metal charges and oxygen refining.

DIRECT REDUCTION OF ORE

Growing scarcity of good metallurgical coke, the high cost of construction of new blast-furnace and coke-oven plants, the ever-present need to provide more fresh metallic units, and the advent of new chemical-engineering techniques (notably the fluid bed reactor) have combined to stimulate anew the search for an effective reduction process that would be cheaper than the blast-furnace. A number have been proposed, generally based on the use of fine ores in fluidized contact with hot reducing gases. Some of these rely on oxygen to furnish, together with appropriate fuels, the reducing medium for the process.

Generally speaking, none of these has yet reached commercial status.* Considerable publicity has been given to the H-iron process, a joint development of Hydrocarbon Research Inc. and the Bethlehem Steel Company. Several others are known to be in advanced laboratory stages, but little authentic information has been released about them.

In H-iron manufacture, finely divided high-grade ore is fluidized in a stream of hot hydrogen gas under a pressure of 400 lb/in^2. The reduction rate at 900° F is rapid enough and the tendency to sticking is not a factor at this temperature. The product is pressed into slugs or briquettes which need to be protected from the atmosphere because of their tendency toward rapid oxidation. A convenient method of providing the necessary hydrogen is by partial combustion (i.e. to CO and H_2) of a fuel, gas or liquid, with pure oxygen. In such processes, catalytic reaction of the CO–H_2 mixture with steam converts the CO to additional H_2 and CO_2; the latter is removed by scrubbing, leaving H_2, usually of 95–98% purity.

Two H-iron plants are now under construction; one, a 50-tons/day unit by the Alan Wood Steel Company near Philadelphia will produce both sinter-grade powder and briquettes.[17] Hydrogen will be secured by partial combustion of coke-oven gas with oxygen. It is expected to test the briquettes as feed material for open-hearth furnaces.

The second will be erected by the Bethlehem Steel Corporation at Los Angeles. Its exact size has not been announced, but it is intended to be large enough to permit reliable costs to be obtained for its operation as well as for ingots made from its product. This would imply a capacity of at least 100 tons/day. Here oxygen will be used with hydrocarbons to provide the hydrogen.

The potential use of oxygen in this application is very large, provided that the process proves economically competitive with the blast-furnace and with other processes that do not use oxygen. To make a ton of iron from hematite requires some 22 000 ft^3 of hydrogen, which, if made from petroleum, will consume about a quarter of a ton of oxygen (6000 ft^3).

It should be pointed out that during the period of development of these reduction methods, roughly corresponding to the last decade, improvement in blast-furnace technology has proceeded rapidly. As furnace capacity has been raised by a variety of means (see above), the unit capital cost and operating expense have come down. As a result, the advocates of direct reduction are looking more closely into projected cost advantages, particularly as these are influenced by location and the nature and cost of local fuels.

* The HyL process at Monterey, Mexico, is making 200 tons of sponge per day, which will be increased to 700 tons/day. In this, the reducing gas is derived from reacting methane with steam in heated catalytic converters.

THE FUTURE

At this writing there would appear to be a very large potential demand for oxygen. Not only the normal growth of the industry but also the economy and quality of oxygen-made steels are forces working in this direction. It is anticipated that the individual steelworks, blast-furnace plant, or pipeline system will require much larger oxygen installations than now exist; output of these will be available at lower costs, possibly opening up new areas for economical use.

ACKNOWLEDGMENT

The author wishes to make grateful mention of the assistance of his colleagues in the Linde Company in the USA and Canada who have supplied much of the detailed information in the paper and have reviewed the manuscript; in particular, Mr A. L. Hodge and Mr J. H. Zimmerman have been most helpful. Further, the kindness of the following individuals, in furnishing information and comment, is greatly appreciated: Mr C. R. Austin (Kaiser Engineers Inc.), Mr D. R. Loughrey (Jones and Laughlin Steel Corporation), Mr J. M. Stapleton (United States Steel Corporation), and Mr J. H. Strassburger (National Steel Corporation).

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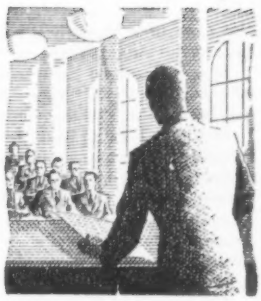
IRON AND STEELWORKS ENGINEERING

The Iron and Steel Engineers Group



Report of the 38th Engineers Group Meeting

The Thirty-Eighth Meeting of the Iron and Steel Engineers Group of The Iron and Steel Institute was held in the Great Hall, Caxton Hall, London S W 1, on Thursday, 11th December, 1958.

The Chair at both sessions was occupied by Mr F. B. George, Chairman of the Group. The discussion on papers presented at both sessions appears below.

Discussion on vacuum processes

At the morning session the discussion was based on the following papers (dates of publication in the *Journal* in parentheses):

"Vacuum treatment of steel by the Bochumer Verein stream degassing process," by *A. Tix, G. Bandel, W. Coupette,* and *A. Sickbert* (1959, vol. 191, March, pp. 260–265). Presented by Dr Bandel.

"Vacuum pouring of ingots for heavy forgings," by *J. H. Stoll* (1959, vol. 191, January, pp. 67–80).

"The vacuum-lifter process of the Dortmund-Hörder Hüttenunion AG," by *F. Harders* (1958, vol. 190, Nov., pp. 306–311).

"The vacuum casting of large forging ingots," by *J. Levaux* and *L. Hanon* (presented by Mr M. Nepper). A revised paper entitled **"Vacuum casting of steel,"** by *J. Levaux* and *M. Nepper* is published in this issue.

"Equipment used for vacuum melting and casting in the iron and steel industry," by *A. S. D. Barrett* and *M. E. Harper* (1959, vol. 191, April, pp. 366–373). Presented by Mr Harper.

Mr **J. A. Mowat** (William Beardmore and Co. Ltd): Vacuum degassing is not a new process, and incidentally, when Mr Stoll made reference to the US patent of 1883 he was about 18 months behind the UK patent which was taken out by Russell Aitken on 29th March, 1882, for the vacuum degassing of molten metals.

When Dr Tix published his paper in 1954 it served to crystallize work and thought which had been taking place all over the world, particularly as it was becoming more and more obvious that the basic electric-arc furnace development was showing the way to better steel. I believe that steel from the basic electric-arc furnace is the steel of the future, and the problems concerning the manufacture of this type of steel are appreciated and are being tackled. Not the least of these is the need to reduce the gas content which is so easily acquired during the process. We can confirm the results shown in Fig. 1 of Mr Stoll's paper.

Various schemes are in operation or planned, to prevent hydrogen and other gases entering the steel. Mr Stoll has mentioned the drying of all additions etc., but suggests it would be impossible to keep out air, but why not introduce warm dried air under pressure? Oxygen lancing reduces the hydrogen content at the oxidizing stage, and inert gas flushing at a later stage is also effective. It is obvious that vacuum degassing does not eliminate the need for care at earlier stages, and as clearly stated by Dr Bandel, "Vacuum treatment obviously does not take the place of careful metallurgical processing, but can only have its full effect in conjunction with such an approach." This is encouraging.

Dr Bandel states that "the original aim of Bochumer Verein and it still is the most important in using vacuum treatment, was to make heavy forgings free from flakes" without, I expect, the long heat-treatment cycles.

It would appear from the papers given today that in practice, using this method, only about 50–60% of the gas content can be removed, and if it is taken that the gas content must be below 1·5 cm³/100 g or ppm to render the forging free from flakes after only a stress freeing treatment, then one would require to tap with a gas content of 3 cm³/100 g. Is that what Dr Bandel means when he says "a hydrogen content of less than 3 cm³/100 g in the liquid steel is sufficient to obtain freedom from flakes" and what Mr Stoll indicates in Fig. 20 of his paper?

It seems that Dr Bandel limits himself to mechanical pumps and Mr Stoll favours steam ejectors. I would imagine a greater vacuum could be produced and maintained by steam ejection than by mechanical pumps, but perhaps the drive for greater vacuum is not necessary as indicated in Fig. 20 of Mr Stoll's paper. Is this so? Does Dr Bandel feel there is anything vital in the method of producing the vacuum conditions?

The speed of pouring does not seem to be vital up to practical limits yet the faster the pour surely the less would be the disintegration of the steam into droplets which is claimed to be the reason for gas removal. Is it a compromise?

When casting an ingot in the vacuum chamber both Dr Bandel and Mr Stoll indicate that the vacuum conditions are modified as soon as the ingot mould is full except in the case of rimming steels. What happens if the ingot is completely solidified under vacuum? In

the case of a large ingot some of it must become solid before the vacuum is removed.

Is it correct to assume that it would not be possible to cast a number of ingots one after the other in a revolving bottom in the one big vacuum chamber?

Both Dr Bandel and Mr Stoll produce graphs to show hydrogen segregation in conventionally cast ingots or forgings from such ingots, and the elimination of such segregation in those which are vacuum cast, but why should this be? Is it a case of diffusivity, for I would imagine the mechanics of solidification would not be greatly altered because the steel starts to solidify with a lower gas content.

The practical possibilities of the principle re-stated by Dr Tix have stimulated thought being given to other possible methods for degassing steel under a partial or complete vacuum. As a result of these thoughts we have to-day heard of the Bochumer process from Drs Bandel and Levaux, and of the US process by Mr Stoll. It has, however, been encouraging to hear of other methods tried and found to be successful. Dr Harders's contribution has been most interesting, and his reference to the benefits of so treating non-alloy steels and the economic advantages of so doing should set us all thinking. He says "it is economical for the forging shop to pay for each ton of vacuum-treated steel an additional amount equivalent to five times the maximum cost of vacuum treatment." All this indicates the wide possibilities of vacuum degassing well beyond large alloy steel ingots.

Mr Harper described another new method, and it is known that there are others being developed throughout the world. Perhaps some members of the audience will be prepared to outline some of these new developments which are rapidly changing the approach to steelmaking and producing better steels for higher and more exacting requirements.

Mr **Z. Z. J. Kosarski** (Sheepbridge Alloy Castings Ltd): Some two years ago, it occurred to us that although vacuum melting and degassing of steel was used almost entirely for the production of ingots, particularly large ingots, where the mould itself is generally located in a vacuum chamber, there might be a good chance of applying to advantage a similar technique in a non-ingot-making foundry, even though neither the centrifugal spinning machines nor the sand moulds could be placed in vacuum, owing to practical difficulties.

Together with Messrs Efco-Edwards we have thus devised a new unit, utilizing our existing high-frequency melting furnace on the lines described in some detail in the paper by Barrett and Harper.

During the short time this unit has been in operation, we have been unable to accumulate any precise data regarding the practical advantages of this method of vacuum degassing, but we have little doubt that in a number of instances it has certainly improved the quality of our castings, if only by reducing the percentage of internal rejects. In common with other users of vacuum melting or degassing plant, we find that lowering the gas content does not affect in general the mechanical properties of the material, except for increasing its ductility. This in itself indicates a higher purity and better quality of the castings. But it is difficult at this stage to state categorically what the practical advantages are of having a vacuum-degassed casting from the user's point of view.

Whilst the use of vacuum degassing contributes to a more economical and satisfactory production of centrifugally spun castings by lowering the percentage of scrap, and also by enabling us in some instances to use cheaper charges in the melting furnace, it is still open to discussion whether it can be used to advantage economically on the majority of alloys, bearing in mind the increased melting time, the cost of lining the holding furnace, and higher handling charges. One of the disadvantages of the unit described is the comparatively short life of the lining when transferring the metal from the normal unit to the holding furnace, particularly if the latter has not been properly preheated. As an alternative, it is possible to melt directly in the holding furnace, applying vacuum to the molten metal at the right temperature, and thus avoiding transfer. But the length of time required is rather prohibitive owing to the design of the coil, which is governed by the comparatively low voltage permissible when operating in vacuum.

In our case, where we had certain melting capacity to spare, the provision of this unit was justified, if only because it helped to a great extent in producing satisfactory centrifugal spinnings in one particular alloy, namely Nimonic 75. It is still debatable, however, whether it is an economic proposition to use this unit for other materials without increasing the price of the finished article. It is more than likely that one would be justified in increasing the price of the finished article owing to the better quality of the material, but at the moment we have not sufficient data to indicate to the customer what practical advantages he gains by using vacuum-degassed metal.

Whilst I am rather reluctant to recommend this unit for use in a non-ingot foundry, I feel that in the light of other papers that have been presented such an induction degassing furnace offers the ingot industry a chance of producing small and medium-sized ingots of higher quality at a comparatively low operational cost and in exchange for a relatively small capital investment.

My company has no facilities for further processing of ingots, nor are we normally engaged on the production of ingots as such. But we should be quite willing to provide some vacuum-degassed ingots for any firm which might be interested in investigating the possibilities of the induction degassing technique.

Dr **P. E. Hammarlund** (ASEA): I represent the company in Sweden that designed and installed the two latest induction vacuum furnaces at Utica in the United States of America which are to be described in Darmara's paper this afternoon. It is believed that the largest of these furnaces, with its 5 000-lb capacity and 1 100-kW power input, is the largest in use in the world so far.

I should like to start from this furnace as a background and to make a few comments on two particular points relating to the paper by Mr Barrett and Mr Harper, namely the upper limit of furnace size and the stirring of melts in vacuum.

The upper limit of furnace size is, of course, of very great economic importance. The bigger the furnace the better is the economy in large-scale production.

The physical size of the furnace is a question of ceramic lining technique. From this consideration, 5 000 lb is not the upper limit. It is no doubt possible with existing lining materials to use, say, 10 000-lb furnaces. The size of the vacuum tanks for a furnace of this size is no problem either.

It is possible to reach inputs of 1 000 to 1 200 kW at 400 V although the very high currents will give high losses. Inputs of, say, 2 000 kW require higher voltages, for example, 800 V. It has been found technically possible to use such high voltages in vacuum by applying solid insulation around the copper tubes of the coil and by covering the outer surfaces of this insulation with corona screens by a special technique that I will not describe in detail.

Summing up, induction vacuum furnaces are available today for 10 000 lb with power inputs of between 1 000

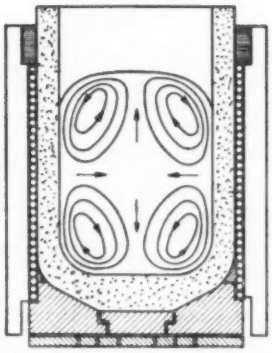


Fig. A—Stirring of the melt by high-frequency or low-frequency single-phase current

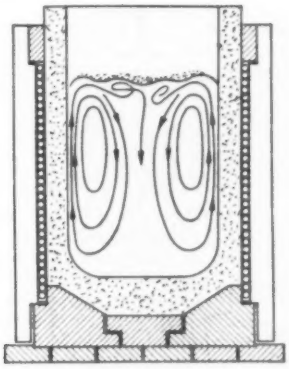


Fig. B—Stirring of the melt in the dual-frequency furnace using polyphase low-frequency current

and 2 000 kW. From this may be drawn the conclusion that the arguments for the duplexing method (described as the induction-degassing method in the paper by Barrett and Harper) become considerably weakened. As it is possible without much extra cost to melt effectively in the vacuum furnace proper, it is questionable whether it pays to introduce the complexity of the duplexing process.

The other point on which I should like to comment is stirring. It is, of course, necessary, as has been pointed out, to have some sort of stirring when trying to degas a stationary melt because of the ferrostatic pressure. The melt at the bottom is subject to the head of melt and must therefore be brought up to the surface. The conventional stirring obtained in an induction furnace is not well suited to this for two reasons. One is that the stirring forces are directed horizontally from the coil surface towards the vertical axis of the melt (*see* Fig. *A*). The other is the annoying fact that the electric power that creates the stirring in a conventional furnace also heats the coil up in a most undesirable way.

Therefore, the technique of using the induction motor type of stirring comes in as a most useful tool. This is achieved by polyphase currents of such a low frequency that no temperature rise takes place. The stirring forces act vertically, taking melt from the bottom to the surface (*see* Fig. *B*). They are superimposed upon the melting current in the coil.

It has been found that this kind of stirring decreases the vacuum treatment time very considerably, apart from having other advantages. I believe that all induction vacuum furnaces in future, furnaces for production, with capacities above 1 000 lb or so, should have this feature.

Finally, I should like to refer to the possibility of vacuum-treating a melt in a large ladle by placing it in a vacuum tank and stirring the melt, as referred to in the Bochumer Verein paper. This stirring can be easily achieved by placing vertically in the vacuum tank a stirrer of the same kind as is commonly used under arc melting furnaces, so that the stirrer comes close to the side wall of the ladle.

By this means the melt is moved from the bottom to the surface. With treatment of this kind, taking some 15 to 20 min, one would expect good results with very simple equipment; and the method is of particular interest to those steelworks that already have arc furnaces equipped with stirrers, as the same generating equipment can be used.

I should like also to say something about the ladle. The most effective stirring is obtained if the wall of the ladle is made of non-magnetic steel, but this is not altogether necessary. With a very strong stirrer it is possible to introduce saturation in a magnetic ladle wall, thereby making it non-magnetic. The only trouble is the cost of making the stirrer stronger than the standard type.

Mr **A. S. Godbehere** (William Jessop and Sons Ltd): My company is faced with the problem which is probably common to many in that we are wondering whether we should introduce vacuum casting and if so, which type of vacuum equipment would be most suitable for our business.

For the production of small ingots we have an opportunity of using vacuum induction melting or consumable arc processes, and for the production of large ingots there is the Bochumer Verein process or the method described by Mr Stoll. The problem that arises for a great many of us is the vacuum casting of several ingots of intermediate size from one heat of steel, where we probably have to pour the steel through a second ladle. We know that we have to keep the hydrogen content extremely low in order to obviate long heat treatment cycles; but when it comes to putting some of that hydrogen back again by subsequently air casting after vacuum casting into a second ladle, we are probably doubtful whether it is really worth while. I am sure that we shall have to study these problems carefully before we are prepared to install such expensive equipment.

I should like to ask Mr Stoll whether he has had any experience at Bethlehem with his 7-ton unit of vacuum casting into an intermediate ladle and then air pouring into ingot moulds. Also, what is the difference in the hydrogen content immediately after evacuation in the ladle and that present in the steel ingot after air casting? Does the hydrogen content rise again to a dangerous level, so that we dare not subsequently process the ingot without first carrying out elaborate anti-hairline crack treatment?

I should also like to ask Dr Harders a question. I believe he stated that following his process there was 2 cm^3/100 g of hydrogen in the liquid steel in the feeder head of the ingot. I should like him to confirm that this 2 cm^3 was actually in the feeder head of the ingot after air pouring, or was this the content in the liquid steel in the ladle immediately after vacuum degassing.

Dr **H. Maas** (Ruhrstahl AG, Hattingen): The reports on stream casting degassing and the vacuum-lifting process prove that these processes are suitable for use on a large scale. As a further possibility for the degassing of large quantities of liquid steel, I should like to mention a process which has become known as 'Umlaufentgasung.' This might be translated 'circulating process.'

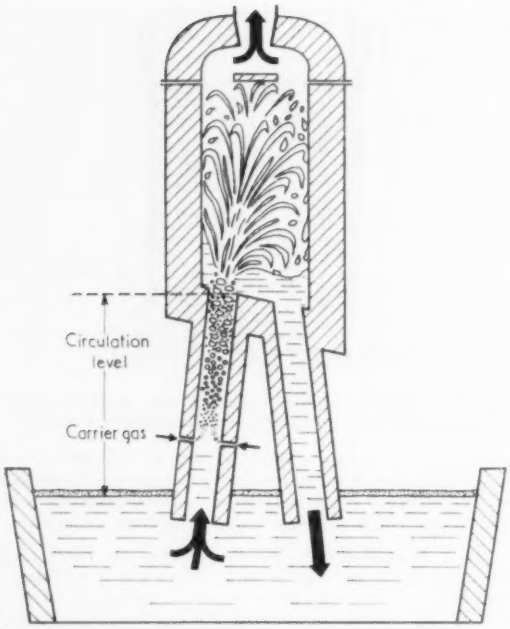


Fig. C—Diagram illustrating the ' circulating process ' principle

Ruhrstahl AG has developed and used this process (which originated from the experiences of Messrs W. C. Heraeus in the treatment of liquid metals) during the past year and a half, when some thousands of tons of steel for large forgings were degassed.

The characteristic of this process is the circulation of the liquid steel through an evacuated degassing chamber (Fig. *C*). The steel is continuously lifted out of the ladle through a rising tube into the degassing chamber and after degassing flows back into the ladle through a second tube. The energy required for its circulation is obtained partly by expansion of the volume of a gas which is added in the lower part of the rising tube and partly from gas released from the steel on account of the vacuum in the degassing chamber. For the transportation of the steel very little gas is required.

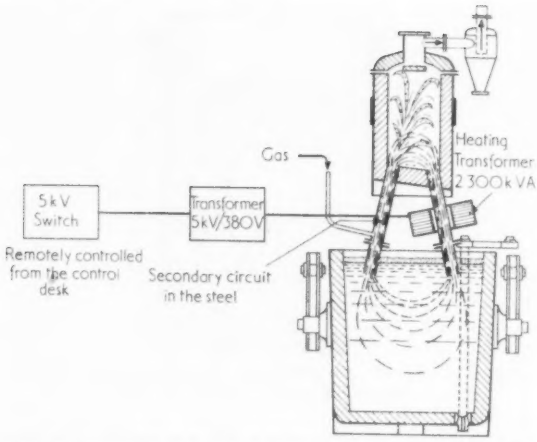

Gas
Heating Transformer 2 300 k VA
5 k V Switch
Transformer 5 kV/380 V
Remotely controlled from the control desk
Secondary circuit in the steel

Fig. E—Method of heating in the ' circulating process '

A special advantage in this process is the favourable distribution of the steel in the degassing chamber. The rising gas bubbles increase in volume one hundred times, and the steel enters the degassing chamber at high velocity, is thrown upward, and by releasing further gases, carbon monoxide and hydrogen, disperses violently. Figure *D* shows a model during a time range of 0·16 s. Due to the favourable conditions, the degassing chamber can be kept small. Any unavoidable heat losses that may result can be kept low.

Nevertheless, we have developed a special method of heating which works on the transformer principle. It may also be compared with the principle of a low-frequency melting oven. In Fig. *E* the transformer is shown in position on one of the tubes. The secondary flux passes through the steel inside the tubes, the steel in the ladle, and the degassing chamber.

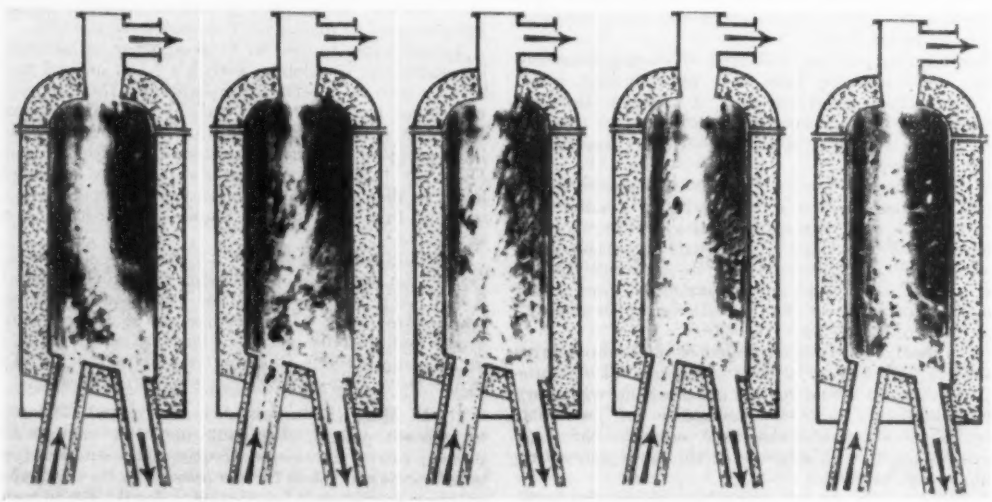


Fig. D—Dispersion of the steel in the degassing chamber over a period of time (mercury model)

The degassed steel flows back at such a speed that it goes right to the bottom of the ladle and so underlies the remaining ladle content. Through this degassing treatment we achieve a medium hydrogen reduction of 40–55%, depending on the type of analysis.

Oxide inclusions are reduced through this process to 0·015%, where normally they are 0·035%.

Mr **T. B. Biernacki** (Sheepbridge Alloy Castings Ltd): I should like to add a few words to what Mr Kosarski has already said about our installation of the vacuum degassing process for the production of steel castings in metal dies. This application is similar to the vacuum-lifter process developed by the Dortmund-Hörder Hüttenunion AG, and also to the ladle-to-ladle vacuum method used for degassing small ingots. It is similar in that the metal after degassing is air-cast in the normal way.

Before commenting on the results of this process, I should like to say something about techniques. The induction vacuum furnace used was described by Mr Harper, who called it an induction holding furnace. The metal is melted, alloyed, and deoxidized in a normal high-frequency furnace in the air, although this can be done in the vacuum furnace itself if desired. The liquid metal is transferred into the vacuum crucible and the vacuum is applied, at the desired temperature for the desired time. Afterwards the metal is poured into the ladle and distributed to the metal dies in the normal way.

The vacuum can be obtained in 10 to 15 min up to about $\frac{1}{2}$ mm Hg. It is also important that vacuum can be maintained for a considerable period, if desired, even 1 h.

In spite of exposure of vacuum-degassed metal to the air during pouring operations, without giving away any secrets, we can say that from somewhat inferior charges for a high-frequency furnace, such as, for instance, oily turnings, we can obtain clean metal with comparatively low inclusion content and with much lower gas content, especially hydrogen content. This results in better ductility of the cast metal and also in freedom from hydrogen defects, such as minute hairline cracks and pinholes. We have also tried to pour the degassed metal into sand moulds, but it would be premature to comment on that.

Mr **G. Wilz** (Denain): We have been told about vacuum pouring from ladle to ladle for steel castings. There must be a big loss of temperature here which makes for difficulty. Dr Bandel has told us of his experience with vacuum pouring for steel castings. Can this be used indiscriminately? Has he any data about improvements in steel castings with this process?

Also, I have noticed a big difference in the pressure range indicated by different speakers. Dr Bandel referred to a pressure of about 10 mm Hg and Mr Stoll to a pressure range of about $\frac{1}{2}$ mm Hg. What is the reason for this difference? Is it a matter of containing the dispersion of the stream, or is there any other theoretical reason?

Mr **J. A. Charles** (British Oxygen Research and Development Ltd): I have been particularly impressed by the contributions made to the discussion by Dr Maas.

There is one aspect of his process I would like him to clarify. Gas is introduced into one of the pipes leading to the vacuum chamber, causing circulation of the steel through the chamber and back down into the ladle through the other pipe. Could Dr Maas tell us what gas was used?

Mr **T. F. Pearson** (Consett Iron Co. Ltd): The authors who described the method of casting *in vacuo* confined their work to large-size forging ingots. We know in such cases that surface defects are cleaned up considerably by repeated reheating and scaling. We have seen from the illustrations how, in vacuum casting, the stream is shattered. I should like to ask what the surface is like on such ingots and whether it would be tolerable as far as imperfections are concerned with a single reheat in a soaking pit and a normal hot-rolling operation.

Mr **J. Hewitt** (The United Steel Companies Ltd): I should like to make two points. First, many of the contributors and authors have referred to the hydrogen pickup after degassing and subsequent teeming in air. We have had a little experience of this at United Steel not with degassed steel, but with ordinary steel. We believe the pickup of hydrogen is not from the air, but from the refractories or from the mould wash in the system.

Second, several of the authors have suggested that hydrogen is segregated in the ingots. We have considerable experience of hydrogen distributions in forgings and a little knowledge of hydrogen distribution in ingots. We find this kind of distribution is not due to segregation but to simple and calculable hydrogen losses occurring during normal heat treatment. I would suggest, for example, that the hydrogen distributions shown by Mr Stoll, and by Dr Tix and his colleagues are due to losses of this kind. If one plotted the percentage change of hydrogen distribution for vacuum- and air-cast forgings the two distribution curves would be the same.

I should like to ask in conclusion if any of the authors have found a pickup of oxygen owing to erosion of refractories during vacuum treatment. One would expect, for example, with ladle-to-ladle degassing quite a bit of turbulence around the metal surface in the ladle, which could result in pickup of oxygen owing to erosion of refractories. This erosion would also be particularly important in the Dortmund-Hörder type of system described. It would seem that we are removing some oxygen by vacuum treatment but run the risk of replacing it by oxide particles from refractories. Must we therefore be very careful in vacuum treatment about the quality of the refractories in the system?

Mr **D. F. Campbell** (Electric Furnace Co.): May I ask two simple questions? Have our friends at Bethlehem had any experience in making large steel castings in sand, cast in the air from metal which has been previously degassed? Second, reference has been made to the machinability of steel after it has been degassed. We are all very interested in machinability, and I should like to know more about the method of testing and what is known about the improvement of machinability by degassing treatment.

Dr **C. L. M. Cottrell** (Bristol Aerojet Ltd): In listening to the various papers, I have come to the conclusion that a lot of the work on vacuum treatment of steel has come about of necessity, the steelmakers have found it necessary to find some way of avoiding hairline cracks, flaking, etc. I hope they are able to produce sound ingots by this method. But to consider another aspect of vacuum treatment of steel, would it not be a good idea if the user obtained the greatest benefit from the steel? From this aspect, especially considering higher quality steels, it would perhaps be a good idea to start with an even better base material. One does not run a high-compression engine on 'pool' petrol. Therefore, why do we put more or less standard grades of material into vacuum-melting furnaces.

Levaux and Hanon use a process for the removal of

sulphur before vacuum treatment. In their paper, they say that they get a considerable improvement in transverse mechanical properties. Is this improvement in part a combination of removal of gas and removal of sulphur, as well as removal of oxides? I should like to leave you with the thought that if we could start with steels very low in impurities we might get an even better improvement by vacuum-melting techniques.

Dr **L. E. Benson** (Metropolitan-Vickers Electrical Co. Ltd): I represent a company which buys and uses some of the large forgings that have been referred to. Whilst some extremely good large rotor forgings have been made in the UK without the use of vacuum degassing, we recognize that the hydrogen degassing process has very real advantages. I would like to ask about a possible advantage that has not been mentioned, but that is of some moment to us.

In a large ingot there is always a segregated zone in the interior and near the bottom which is characterized by a rather lower carbon content than the average. As a consequence when this part of the ingot is made into a forging, say a turbine rotor, there may be an area within the forging that has lower mechanical properties than the material generally, and lower than the normal test pieces which come from the outside.

Is it possible that by the degassing process this segregation effect will be reduced? At first glance it is not easy to see why it should be. On the other hand, this area of the ingot which is characterized by a low carbon content is also characterized by the presence of silicate inclusions. It is known that vacuum casting has some effect on the inclusions present in an ingot. If, therefore, there is some association between the carbon content and the inclusion content of the bottom cone both might possibly be affected by vacuum casting. Is this so and if so is the effect of vacuum casting advantageous?

Dr **Bandel,** in reply: Whether vacuum treatment can be expected to improve the properties of the steel and whether it can help to reduce inclusions in the lower part of a large ingot are questions that have often been asked, but so far we have not a complete answer to them. There is an improvement in properties, but it is not due to vacuum treatment alone.

The question has been asked whether after degassing from ladle to ladle the temperature losses are too high. We have temperature losses, but it is surprising that the steel has very good fluidity. We have found an improvement in porosity in thin sections of 13%Cr steel.

We do have to avoid stresses in rolled steel, but there are new methods of two-stage degassing where the stresses are very low.

After ladle-to-ladle degassing and air pouring there is an increase in hydrogen and oxygen, but this increase is very low. This has been considered by Dr Tix in *Stahl und Eisen* (1956, vol. 76, pp. 61–68).

Mr **Stoll,** in reply: First of all, my apologies to Mr Mowat for my error in the date and authorship of the original patent.

In reply to Mr Mowat's question concerning Fig. 20 of our paper, heats containing as high as 4·5–5·0 ppm hydrogen before degassing have been processed with complete freedom from flakes. On Mr Mowat's second point concerning Fig. 20, it is not intended that this chart in any way be extrapolated. Our experience has indicated effective hydrogen removal within the limits indicated of 400–1 200 μ.

On pouring rates, it is safe to assume from a theoretical standpoint, that if pouring rates were increased infinitely, the degassing efficiency would be decreased. However, within our experience, variation of pouring rates has made no significant difference in degassing efficiency.

We have had no experience of an ingot 'completely solidified under vacuum.' On the possibility of casting a number of ingots one after the other in a revolving bottom in the one vacuum chamber, such an installation is being tried out in the USA, but we have no information on the results.

On Fig. 23, the question is raised as to why hydrogen segregation should be eliminated in a vacuum-cast ingot. We believe hydrogen in an ingot should be considered not as segregation but rather as a matter of distribution. The generally accepted explanation of the high hydrogen at the centre of an air-cast forging is that hydrogen is unable to get out or diffuse from the centre through the large mass. In a vacuum-cast ingot, the lower hydrogen level does not create the same high internal pressure, thus resulting in a uniform distribution throughout the cross-section.

In reply to Mr Godbehere, our experience with intermediate ladle degassing is limited. It has been confined to the small 7-ton development unit. On nine ladle-degassed heats, an average of 0·6 ppm hydrogen has been picked up when metal from the degassed ladle was poured into small ingot moulds. The pickup is influenced by the relative humidity of the air during air-pouring. As to whether this average pickup of 0·6 ppm would cause flaking, it is difficult to say. On small ingots rolled to blooms, the slight rise in hydrogen would be of little significance. On a large forging where the aim is for the lowest possible hydrogen, even the 0·6 ppm pickup would be undesirable.

Answering the points raised by Mr Wilz, experimental degassing at lesser vacuum was found unsatisfactory and inefficient during development work. Since our ejectors are capable of producing a pressure range of 1½ mm Hg and degassing is efficient and controllable at this level, it is preferred to operate in this range.

To Mr Pearson we say that our experience is limited to our 7-ton unit, but we have satisfactorily rolled, without undue conditioning or extraordinary heat treatment, ingots cast in vacuum. This is something which in our operations we do not at the moment anticipate as a problem.

We agree with Mr Hewitt that there is no such thing as hydrogen segregation, and that the distribution of hydrogen in a forging is the result of diffusion occurring during normal heat treatment. In reply to his question on refractory quality, in vacuum, reaction and gas evolution from refractories can occur which does not ordinarily take place at atmospheric pressure. Accordingly, the choice of refractories for vacuum service is important.

To Mr Campbell, we have had no experience in making large steel castings in sand using ladle degassed metal, although future work is contemplated.

Dr Benson asks whether the segregation effect will be reduced by degassing. He refers particularly to the bottom of a vacuum-cast ingot and whether it is anticipated that it will be improved from the standpoint of negative segregation and silicate inclusion content. On the points raised by Dr Benson, in making large ingots at Bethlehem it was the practice in air casting and is also the practice in vacuum casting to utilize the product of several different heats melted simultaneously. We attempt to minimize bottom segregation by selective melting aims for the individual heats. In other words, we may start with a heat two points higher in carbon than required. The subsequent heats would have lower requirements while the top heat might be made two points lower than the final carbon required. Thus the effect of the natural trend for segregation is minimized. The problem of negative segregation is further aided by heavy bottom discards, which is standard practice.

As to inclusions in this area and what effect vacuum pouring might have, we know that silicate inclusions are lower in the vacuum-cast product and therefore would anticipate improvement in this bottom cone area.

Dr **Harders,** in reply: I can confirm that 2 cm^3 of hydrogen are found after degassing in the normal ladle under air used for pouring off the ingots.

We use copper ingot suction moulds and the samples are fused in high vacuum at about 3 272° F to remove hydrogen.

With regard to oxygen being supplied to the degassed steel from the ladle lining and to slag in the steel, this does not take place according to our detailed tests. We use ladles with normal linings and no reaction with the degassed steel has been observed. Slag is dealt with by means of lime to counteract reaction with degassed steel. The slag-free ladles are covered with conventional covering material normally used for ladles. There have been no difficulties in this respect.

Concerning machinability, I refer you to a recent paper in *Stahl und Eisen* in which it was reported that the life of turning tools would be about 50% better.

Mr **Z. Z. J. Kosarski** (Sheepbridge Alloy Castings Ltd): Although I am not the author of any of the papers, perhaps I could reply to one or two of the questions that were raised earlier.

I would like to confirm the statement made previously that there is no appreciable pickup of hydrogen when vacuum-melted or vacuum-degassed metal is poured in air. In one case when we stream degassed a nickel-base alloy in one of our vacuum units, we checked the hydrogen content immediately after treatment and again in the ladle after transferring in air, and found no difference whatsoever.

The gas analyses, which were determined for us by the BISRA laboratories at Sheffield, were as follows:

Nickel-base alloy	*Hydrogen, $cm^3/100\,g$*
In transfer ladle for stream degassing	4·3
In furnace after degassing	1·5
In ladle after air transfer	1·5

With regard to hydrogen in actual castings, we found that with centrifugal die spinnings in 13%Cr steel which normally give us up to 10% rejections for 'flakes,' a run of some thirty vacuum-degassed heats did not show one rejection at magnetic crack detection. Since in this process the metal was transferred in air to the casting ladle and again was exposed to air for considerable periods of time during introduction to the spinning machine, we consider that for practical purposes there was no significant hydrogen pickup.

We have no experience to suggest whether or not degassing to remove hydrogen improves the quality of sand castings.

Mr **Nepper,** in reply: It may have been noticed that we are applying vacuum casting of big ingots to steels made in the basic open-hearth furnace with additional treatment by the Perrin process. We started with this refining technique and we got high-quality steel, low in sulphur content and reasonably low in inclusions.

First, there was an improvement in hairline cracking, and then there was an improvement in transverse properties owing to a reduction in the amount of inclusions. However, there is still more to be done. What is detrimental in a big forging is the association of inclusions with hydrogen in an air-cast forging, and even with our process we get inclusions. We got a core of oxide in a matrix of silicate. The lack of deformability and the difference in deformability between different parts of the inclusion caused some porosity. In porosities, the pressure of hydrogen may initiate some cracks. With vacuum cooling not only is the hydrogen content reduced but the inclusions are fewer and well spread. The main step forward is that the initiation of cracks becomes impossible.

Mr **Harper,** in reply: The main answer I want to make is to Dr Hammarlund. First, I should like to emphasize that the induction degassing furnace described is intended to be completely complementary. There are a large number of manufacturers in the UK and elsewhere who already have the requisite electrical equipment and who require to improve their products from relatively poor starting material.

If the price is not to be excessive, the cost of capital equipment is important, and the induction degassing furnace is capable of working in conjunction with existing installations and operating from existing electrical equipment, thus avoiding the high capital expense of special high-power equipment, particularly for vacuum melting. However, that is not to say that for very special lines vacuum induction melting can be replaced.

It does seem probable that there are very good possibilities in the use of liquid charging. For example, the actual cycle time of the furnace relates to the production that can be obtained from the furnace. If the melting is carried out in the furnace, the actual time to melt plus time to refine gives the total cycle time. In the induction degassing furnace the melting time is avoided. It is thus possible for this type of furnace to work in conjunction with more than one melting furnace should a higher rate of production be required.

Suppression of corona at high voltages can now be obtained, and therefore problems are being eased.

One broadly associates the use of high-vacuum induction melting with the choice of a suitable standard of material. It is rather difficult to charge oily scrap into a true vacuum induction melting furnace. However, such material can be used by the duplexing operation. This is an interesting point so far as the metal supplier is concerned, as it reduces melting cost.

I would agree with Dr Cottrell that obviously for certain alloys it is necessary to choose very carefully the starting material. If the maximum improvement is required, one must not expect a vacuum to be able to work miracles, but must relate it to the starting product which must be of high quality.

With regard to refractories and the life of linings, it should be possible to increase the life of linings by continuous working, so that the temperature of the crucible is not lowered sufficiently to cause a large amount of thermal shock. This may require shift work, and production requirements must be such that this is capable of being carried out.

A lot still remains to be done on refractory linings, and they are still far from satisfactory. The method of putting in the linings is important, and we favour putting them in, not by the conventional method, but by the use of graphite blocks and ramming the mixture and fritting the crucible at a higher temperature than normal with a liquid charge.

Dr **Maas:** In reply to Mr Charles, the gas we normally use is argon, but it is possible to use other gases. The pressure of the lifting gas depends on the ferrostatic pressure of the steel at the point of entry of the gas. It is possible to use 50–200 l./min or normally 100 l./min, which is only 5–10% of the gas released from the steel, depending on the type of steel.

Discussion on vacuum steelmaking

At the afternoon session the following papers were presented and discussed (dates of publication in the *Journal* are in parentheses):

"Vacuum-induction melting," by *F. N. Darmara, J. S. Huntington,* and *E. S. Machlin* (1959, vol. 191, Mar., pp. 266–276)

"Vacuum-melting of steels," by *H. C. Child* and *G. T. Harris* (1958, vol. 190, Dec., pp. 414–431)

"The behaviour of various elements in vacuum steelmaking," by *G. M. Gill, E. Ineson,* and *G. Wesley Austin* (1959, vol. 191, Feb., pp. 172–175).

The first paper was presented by Dr **R. Genders** (Consultant) in the absence of the authors. The other two papers were presented respectively by Mr **Harris** and Mr **Gill.**

Dr **J. W. Rodgers** (ICI, Metals Division): The choice of a representative of the non-ferrous industry to open the discussion on the vacuum melting of steel is an indication of the amount of cross-fertilization which is going on between the two halves of the metallurgical industry. This is understandable, since some of the processes described in the papers have been forced on the manufacturers of the newer and more reactive metals because of the difficulties imposed by the special properties of these metals on their manufacture. Once experience has been gained in the operation of these processes and a true economic appreciation of their status has been arrived at in dealing with the more reactive metals, it is apparent that they can have some application to the more conventional materials. The steel industry has obviously not been slow in taking advantage of some of these newer processes, an action which will be of advantage if it can very firmly resist thinking too much in terms of production levels more appropriate to the newer metals.

Without denigrating the efforts of the pioneers of the vacuum melting of steel, it is not unfair to say that until recently the evidence put forward by the proponents of the vacuum melting of steel as to the beneficial effects on mechanical properties has been scanty, and not entirely convincing. Most of the work was really an investigation of the melting process itself. The papers presented today, however, have done much to remove these residual doubts as to the technical efficacy of vacuum melting in improving the mechanical properties.

The methods of melting discussed in the three papers are melting by high frequency and casting in a vacuum chamber, and melting by consumable electrode in an evacuated water-cooled crucible, allowing the molten metal to solidify *in situ*. Using one or even both of these methods of melting, four main processes leading to improvements in the quality of the products, compared with that resulting from more conventional melting procedures, can take place. First, dissolved gases are removed, second, volatile impurities may be removed or reactions between constituents promoted by the removal of gaseous by-products, third, non-metallic inclusions, particularly oxides, can be prevented from forming, though this is not peculiar to vacuum melting and can also happen in melting in a protective atmosphere furnace. Also, non-metallic inclusions can be either decomposed or dispersed, so that they are very much less harmful. Fourth, reduction in effectiveness of certain valuable constituents can be avoided. These constituents are introduced because of the effect which they have on the properties of the metal, but it is extremely difficult to keep them there because of their reactive nature. Aluminium, in particular, comes into this category.

I think that it is fair to say that the advantages of removing dissolved gases appear to be somewhat limited. There is, it is true, an advantage to be obtained by allowing the reactions to proceed rather further than they can under conventional melting procedures, and in that way porosity can be reduced. Also, a certain amount of the mechanically induced segregation can be avoided, because the gases are not there to push the metal about from one part of the ingot to another. There seems, however, to be some doubt whether or not the removal of truly dissolved gases in the solid solution has any significant effect on the mechanical properties.

If, however, we accept the fact that the actual physical removal of gases is highly desirable, both methods appear to be quite effective, although Child and Harris claim that the vacuum-induction furnace is to be preferred on account of the longer time available for the removal of gas. I think that some users of vacuum-arc furnaces would contend that there is some evidence that the higher temperatures occurring in the arc, combined with the appreciable amount of atomization which occurs when metal is transferred from the electrode to the molten pool, to some extent redress the balance between these two melting methods, although it is necessary to make certain that the conditions inside the furnace are suitable, and in particular that there is plenty of room between the electrode and the wall of the crucible for the extracted gas to escape.

There is now a fair amount of evidence that the removal of volatile impurities is feasible and generally beneficial, though Child and Harris point out that there are occasions when the removal of volatile materials has a deleterious effect. The paper by Gill, Ineson, and Wesley Austin has shown how this can be done, and they give some interesting data about the relative efficiencies of the two melting methods. It is only right to point out that their data on vacuum-arc melting relate only to the small furnace using 1-in. dia. ingots and cannot, therefore, be considered as truly representative of large production furnaces such as are now in operation. Their main findings on the lower efficiency of the vacuum-arc furnace, however, are supported by the observations of Child and Harris, who, incidentally, do not quote any figures on this subject, and also by indirect evidence which we have obtained during our own experiments on the vacuum melting of steel; but both methods of vacuum melting can be relied on to remove some of these objectionable volatile constituents and lead to enhanced mechanical properties.

The third process is the prevention or removal or dispersion of non-metallic inclusions. In this case the use of combined melting and casting in one protective container for the prevention of oxide films seems obvious, though it does not minimize the vacuum engineering problems associated with carrying out this process on a large scale, and there appears to be an upper limit to the size of ingots which can be cast by high-frequency furnaces.

With respect to the effects of vacuum-induction melting on non-metallic inclusions, the position is not so clear. In so far as inclusions arise from the constituents of the charge itself, Darmara, Huntington, and Machlin claim that this method is more suitable for their removal, since a longer time can be allowed for getting them out, and this is not in fact available in the vacuum-

TABLE I

Manganese loss in consumable-electrode vacuum arc melting

Heat	Ingot dia., in.	Steel type	Manganese, %		
			Electrode	Ingot	Loss
A	6	3%Cr–Mo	0·49	0·40	0·09
B	6	3%Cr–Mo	0·48	0·42	0·06
C	6	3%Cr–Mo–V–W	0·31	0·24	0·07
D	6	3%Cr–Mo–V–W	0·31	0·30	0·01
E	6	3%Cr–Mo–V–W	0·32	0·26	0·06
F	6	5%Cr–Mo–V	0·55	0·48	0·07
G	6	12%Cr	0·90	0·90	nil
H	6	25%Cr 18%Ni	2·10	2·01	0·09
I	6	C–Cr	0·28	0·24	0·04
J	6	C–Cr	0·27	0·23	0·04
K	16	C–Cr	0·33	*†0·29	0·04
L	16	C–Cr	0·33	*0·24	0·09

* Manganese in ingot erratic
† 1·90% manganese in spattered film from ingot mould

arc furnace. Child and Harris, however, claim that at any rate some types of inclusion are dispersed and rendered innocuous as they pass through the arc and our own experience supports them in this.

There is some difference in the opinions expressed in these three papers as to the extent to which erosion of the refractory in vacuum-induction melting can be taken into consideration. Darmara *et al.* suggest that it may contribute significantly to the oxygen and other impurities, apart from refractory particles which may be physically dispersed in the metal. We should like more information on this point. Child and Harris do not appear to be quite so certain about this. They refer in Table VIII and on p. 423 to the advantage that the consumable-electrode has over the vacuum-induction furnace in that no refractory materials are used, but on p. 424 they suggest that the vacuum-induction furnace can be used provided the non-metallic inclusions are kept low by carefully selecting low-sulphur raw materials. Can it be inferred that they consider that there is in fact little hazard to be encountered from the magnesia-alumina refractories used in the induction furnace?

I need not say much about the loss of reactive constituents such as titanium and aluminium. There appears to be no doubt at all about the efficacy of the vacuum-melting process in preventing loss by oxidation.

The ultimate problem in assessing the importance of the vacuum melting of steel is that of cost, and here there is a considerable difference between the two processes. The vacuum-induction process is limited to relatively small ingots and, because of the necessity of outgassing the refractory, time cycles are lengthy. On the other hand, the melting cycle of the water-cooled crucible arc furnace is short and steel ingots up to several tons can be cast with very little trouble. The equipment is basically inexpensive although safety precautions, which must be introduced for melting titanium, which is a much more reactive metal, have made the capital cost of the furnaces and the surrounding protective devices very much higher than was originally expected.

Nevertheless, the cost of vacuum-induction melting, and indeed the cost of vacuum melting generally, is very high by normal steel melting standards, and 2*s* 6*d*–3*s* 6*d*/lb has been quoted (not in these papers) for

TABLE II

Comparison of losses of hydrogen, oxygen, and nitrogen from low-alloy steels in vacuum-steelmaking processes

Process	Hydrogen	Oxygen	Nitrogen
Vacuum casting	30–80% removed	Small or moderate loss, up to 0·006%	Small loss up to 0·004%
Consumable-electrode arc melting	Almost complete removal expected	Considerable loss, less than 0·002% usually remains	Small loss up to 0·004%
Vacuum-induction melting	Almost complete removal expected	Considerable loss, less than 0·002% usually remains	Considerable loss except when chromium content is high

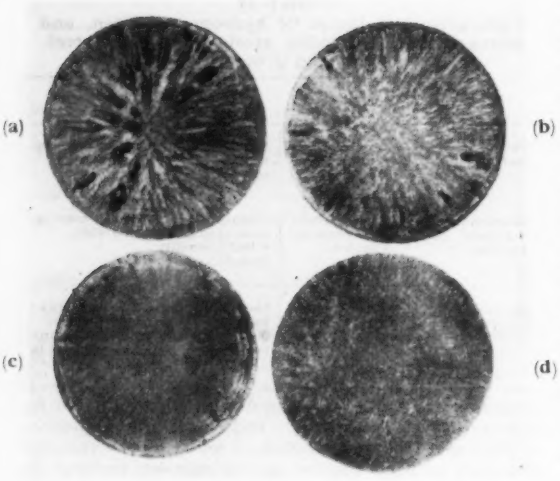
vacuum-arc melting, compared with about double for vacuum-induction melting. Indeed, if the suggestion of Child and Harris is adopted, of following the vacuum-induction melting process by vacuum-arc melting for certain materials which justify it, the cost is going to be very much higher. Very substantial improvements in the quality of the ultimate product will be needed to justify these high costs, and it is possible that many of the advantages claimed for vacuum melting might be achieved more cheaply by spending more money on selecting high-quality raw materials.

Dr **J. D. Hobson** (Hadfields Ltd): There are three points arising out of the papers that have been presented which I wish to discuss.

In the paper by Gill *et al.* the authors conclude from the results of small-scale vacuum melting that in the consumable-electrode arc-melting process the volatile elements are manganese, copper, tin, and lead. We have examined several heats made by this process to give ingots of 6 or 16 in. dia. and have found a systematic loss of manganese, oxygen, and nitrogen. No doubt hydrogen would also be almost completely removed, but we have not been able to check that point. Table I shows the losses of manganese we have found; these are rather erratic, but the mean is about 0·06%.

We have also been able to experiment with vacuum casting, and to compare the changes in gas content in this process with vacuum melting by induction and by the consumable electrode arc process. The figures are summarized in Table II. The results show that vacuum casting produces a very good removal of hydrogen; the process is more efficient when the initial hydrogen content is high and when the pressure is low, but in our experience a vacuum of the order of 10–20 mm Hg is sufficient to reduce the hydrogen content to about 2·0–2·5 ml/100g. With faster pumps this performance would probably have been improved. In low-alloy steel about 0·003%N is also removed and appreciable amounts of oxygen, up to 0·006% in favourable cases. One difficulty experienced is that the liquid steel in the mould tends to boil when the steel reaches the ingot head, making the latter difficult to fill. When the vacuum is broken the boil stops and the steel sinks considerably so that the head is not full. I would like to ask the authors who have experience of large scale vacuum-casting plant operation whether they have this difficulty or whether the much larger area of steel exposed allows the gases evolved to escape without undue rising of the liquid surface.

Figure *A* illustrates some cross-sections of 6-in. ingots made by the consumable electrode process, showing two difficulties we have met. Firstly, I would draw your attention to the bright areas on the section. Semi-



(*a*), (*c*), and (*d*) Bottom, middle, and top slices from ingot E, 3% Cr–Mo–V–W steel, showing porosity and banding
(*b*) Middle slice from ingot C, 3% Cr–Mo–V–W steel, showing banding

	centre	mid-radius	edge	bright band
Carbon, %	0·22	0·22	0·19	0·14
Nitrogen, %	0·012	0·013	0·012	0·010

Fig. A—Porosity and banding in ingots made by consumable-electrode vacuum melting

micro analysis has shown that the bands have a much lower carbon content than the rest of the ingot, 0·14% against 0·22% respectively. Secondly, you will have noticed the porosity which increases in severity towards the top of the ingot.

This trouble has been found in three separate heats of 3% chromium–molybdenum–vanadium–tungsten steel and in no others. It seems likely that a carbon–oxygen reaction is responsible since the trouble persisted when vacuum-cast material was used for the electrode, thus eliminating excessive hydrogen as a possible cause. The latter electrode also had a low oxygen content, and therefore the explanation based on a carbon–oxygen reaction in the liquid pool is rather unsatisfactory. I would be glad to hear whether the authors with experience of consumable-electrode vacuum melting have encountered similar difficulties and whether they can indicate the cause.

Mr **H. C. Child** (Wm Jessop and Sons Ltd): I should like to focus attention on two points in the papers this afternoon. First of all, the papers have brought out the fact that purification reactions are time-dependent, and the paper by Darmara, Huntington, and Machlin has also shown that the purification is size-dependent. I think that this is a very important feature, and it must also apply to the arc furnace. Dr Rodgers has already touched on this as regards the BISRA work, but in an arc furnace melting 1-in. ingots the time that the metal has been molten must be very small indeed, and one would expect that with, say, a 24-in. ingot the time that a particular bit of metal was molten would become comparable to that in the induction process. This emphasizes that when we are studying these purification reactions we must study them under similar conditions of time and temperature, and therefore the size of the melt enters into it in both cases.

One of the features of the arc process which has made it popular is the type of ingot solidification. Darmara *et al.* point out in their paper, without going into details, that in the vacuum-induction process one might expect to use much slower pouring rates, beacuse there would be no danger of contamination of the pouring stream. This is a very interesting thought, and I wonder whether or not anyone here has any information on how slow a pouring rate the authors have in mind. Taken to the extreme, it might be possible to obtain comparable degrees of ingot soundness to the vacuum-arc process if these pouring rates could be reduced sufficiently far.

Mr **W. P. Rees** (NPL): We should like to congratulate the Iron and Steel Engineers Group on arranging this meeting and on the presentation of such a number of very interesting papers on vacuum melting. Our congratulations are the warmer because at the NPL we have always emphasized the importance of studying pure metals and pure alloys, and it was very early recognized that melting *in vacuo* was one comparatively easy way of ensuring freedom of contamination from oxygen and nitrogen during the melting of the alloys. As long ago as the early 1920's we were producing 6-lb ingots of fairly high quality iron, and a little later 10–20-lb ingots of Ni–Cr iron which had been melted *in vacuo*. After the last war, in 1945–46, a 25-lb vacuum-melting furnace was designed and installed. It was of great interest to me to see how similar the furnace which we designed at that time is to the large furnace described by Child and Harris. We have emphasized quite frequently to visitors that we could see no reason why this small scale should not be pushed up to a considerably larger size, and a few years later we ourselves increased the size of our 25-lb furnace to 50-lb with almost no alteration.

I was interested to read in the paper by Darmara, Huntington, and Machlin that there were many advantages in the horizontal tank over the vertical tank when using induction melting, because that agrees with our own assessment of the two types of tank. There is certainly an advantage on the small sizes, particularly greater facility in handling both the furnace and the furnace lining and the ingot into the ingot mould.

When the 25-lb furnace was installed, the available pumping equipment would only ensure a vacuum of the order of 50 μ Hg, although in the cold the pumps could bring the whole tank down to a pressure of about 1 μ Hg. That, however, was not so great a disadvantage as it seemed, because we were not relying for the purification of our iron and iron alloys merely on evacuation, or the distilling off of the impurities; we were using a hydrogen treatment, because one of our main impurities was oxygen, a highly important impurity in iron alloys, and we removed that by treatment with hydrogen. By this means we had no difficulty at all in bringing down the oxygen and carbon contents to the range of 7–15 ppm.

Now that industry is becoming much more actively interested in vacuum-melting processes, consideration might be given also to the possibility of gas refining using hydrogen. It has many advantages, and, while many feel that large quantities of hydrogen might be dangerous, it need not be dangerous in this case.

The papers by Child and Harris and by Darmara *et al.* mention the improvement in the fatigue properties of chromium steels by vacuum melting. This was demonstrated by work done some years ago for the Inclusions Sub-Committee of BISRA and reported by Mr Frith in Special Report No. 50 of The Iron and Steel Institute. There we took a commercial steel and melted it in our 25-lb furnace. The steel was comparatively gassy and we could not get below 1·5 mm Hg, but even 20-min melting at that pressure resulted in an improvement in the fatigue properties, and authority for that is given in the paper by Mr Frith.

The experiments reported by BISRA are very interesting and, I think, quite important. Some of the data

in Table I have now been superseded by more recent and rather more accurate determinations. I shall not go into the alterations which should be made to that table to bring it up to date, for the greater accuracy does not in any way invalidate the authors' conclusions. I notice that they comment on the curious behaviour of silicon. I feel that the behaviour of tin, judging from the data given in Table I, is rather unexpected, and particularly the very rapid elimination of tin by the vacuum method.

Dr **J. M. Capus** (Mond Nickel Co. Ltd): The paper by Gill, Ineson, and Wesley Austin is a welcome contribution to the metallurgy of vacuum melting, particularly because it draws our attention to the possibility of removing residual impurity elements. In previous papers and discussions we have heard much about the importance of vacuum melting and casting from the points of view of degassing, homogeneity, and the reduction of inclusion content. Important as these are, it is useful to see what other advantages may accrue from the application of vacuum treatment.

The removal of certain elements can have an important effect on the embrittlement of steels. At the laboratory of The Mond Nickel Company, Dr Balajiva and I have been investigating the influence of minor elements on two types of embrittlement in hardened-and-tempered low-alloy steels.

It was found that nickel-containing steels prepared by vacuum-melting using high-purity materials and pure furnace refractories were free from the embrittlement, associated with commercial steels when tempered in the range 250–450° C, which produces the familiar 'trough' in curves of impact value *v.* tempering temperature. This was not a question of lowering the impact–transition temperature so that the impact trough occurred only below room temperature. The impact–transition temperature was determined and found to decrease continuously with increasing tempering temperature, without the usual reversal at about 350° C. The high-purity steels were not prone to temper-brittleness, as judged by tests involving isothermal re-heating at 450° C after tempering at 600° C or slow cooling from the tempering temperature.

Both types of embrittlement occurred when elements such as phosphorus, arsenic, antimony, and tin were added to the high-purity steels. Manganese was also found to induce isothermal embrittlement, but nitrogen was not.

In a more recent investigation it was found that nitrogen could embrittle a steel in the quenched-and-tempered condition. Figure *B* shows the curve of impact value *v.* tempering temperature for a high-purity-base 3% Ni–Cr steel containing 0·02%N. The trough in the impact curve indicates that the embrittling effect of nitrogen manifests itself in the range 250–300° C.

In connection with these effects it is interesting to see that, as stated by Gill *et al.*, tin and manganese may be almost completely removed during vacuum-induction melting. I should like to refer briefly to arsenic and antimony. The comparatively ineffectual removal of arsenic shown in Table V is surprising. The vapour pressure of this element has not been given in the paper, but the indications in the literature* are that it is high, of the order of 1 atm at about 600° C. I wonder if it is the low activity of this element in dilute solution in iron that retards its removal? Have the present authors any views on this?

There are no data in the paper regarding the removal of antimony. The high vapour pressure of antimony

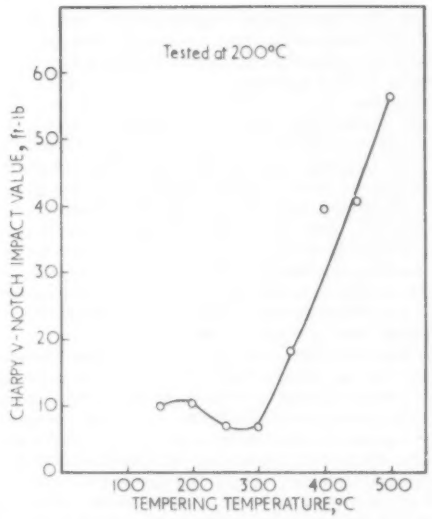


Fig. B—The effect of tempering temperature on impact values of a high-purity-base 3%Ni–Cr steel containing 0·02%N

shown in Table I of the paper suggests that antimony could be effectively removed by vacuum treatment. Have the authors any evidence of this?

A number of the elements which can occur as impurities in commercial steels are largely removed by good steelmaking practice. The authors show encouraging results which lead one to speculate that there may be further development in the combination of vacuum treatment with some other refining treatment for the production on a commercial scale of steels providing improved mechanical properties.

Mr **Carl B. Post** (The Carpenter Steel Co., Reading, Pa, USA): It is most gratifying to be asked to make some remarks at such an excellent technical meeting as this on vacuum degassing and vacuum steelmaking. At the Carpenter Steel Company we have 1 000 tons/year melting capacity by means of a 1 600-lb vacuum-induction furnace, and 3 600 tons/year melting capacity from two 20-in. dia. vacuum consumable-electrode furnaces. Our electric arc furnace capacity is now 160 000 tons/year, so that vacuum-furnace work is still a very small percentage of total steelmaking capacity, which is true of all steel companies in the USA.

Most of the vacuum melting capacity in the USA is dedicated to the needs of the aircraft engine industry. Therein lies a problem, because when dealing with the engine builders it is extremely difficult to know what the demands will be from one month to another, so that schedules are difficult to maintain. That is one big problem which we have to overcome. We like to keep only the ultra-high-temperature alloys in the vacuum-induction furnace and the 1 200–1 300° F high-temperature alloys in the vacuum consumable-electrode furnace.

This is a continually changing field in the USA and I expect that that is true in the UK also. For instance, we are doing as well at present in melting the A.286 alloy in the electric arc furnace as the industry is doing in the consumable-electrode furnace. To enable you to appreciate that statement I ought to say that about eighteen months ago some people discovered that they were getting better steel out of the vacuum consumable-electrode process, and that became the order of the day. A particular batch looked good, but some

*W. A. Fischer and A. Hoffman: *Arch. Eisenhütt.*, 1958, vol. 29, pp. 339–349.

other batches from those furnaces have not looked so good. We make this statement even though we have two 20-in. consumable-electrode furnaces for which we are trying to find business.

A company in the USA called Kellogg uses a non-vacuum consumable-electrode method, using a slag as conduction medium. This slag is a good conductor of electricity and, contrary to what might be imagined, this steel is as good as the A.286 which can be bought in the USA. It seems that with these high-titanium alloys, with 2–3%Ti and 0·5%Al, the slag has a marked effect in cutting down the peripheral surface dirt found with vacuum consumable-electrode melting, so that in addition to getting a uniform structure across the section, due to the water-cooled consumable electrode set-up, it is also free from peripheral dirt.

This can be a very confusing field, especially for those who have to put up the money for it. The main reason for all this activity is the demand of the design engineers, especially in the aircraft industry. It is hard to get them to make general observations, but in my experience in the USA design engineers are not much interested in getting higher values out of any particular alloy; what they want is more consistent reproducibility of the values obtained, with less frequently occurring low values when any physical test is carried out. At the present time, they will pay almost any price for steels of this type.

At the time that vacuum induction started, the alloy S816 was popular in the USA for forging. Most of the steel companies did not want to take the scrap back, and with a price of 5–7 dollars/lb the Services could not understand why their scrap was not worth a lot of money. The Air Force subsidized the first furnaces with the idea of trying to re-melt their forging scrap and use it over again. That is how this business started at Utica, and from there it has grown into an operation of some size.

It is necessary to be careful about the comparison of vacuum-melted steels with conventional electric arc melting. For instance, I wonder why Darmara *et al.* prepared Fig. 14 in which they compare the high transverse test figures for the vacuum-melted material with the low transverse test figures for the air-melted material? That slide annoyed me when I first saw it, some years ago, and so I went back to the Crucible Steel Company and they dug out the data on which it was based. It is difficult to imagine more ill-devised data. The high vacuum transverse data were obtained on ingots of about 9-in. section, and probably selected at that. The other data were from a routine melting shop crucible normally melting 18- to 20-in. square ingots. Some time after that, Republic Steel published a paper showing the difference it made if the transverse section test was made in the equiaxed grains, or in the columnar section, or at the boundary of the columnar and equiaxed grains. To my mind the comparison means nothing. It is admitted that under the right conditions and with the right techniques it is possible to show some difference in transverse values, but I think that most of us feel that transverse testing is related more to ingot structure than to the mode of melting.

Figure 9 shows how close it was possible to hold the analysis with boron. It is not possible to make an induction-vacuum melt without getting some amount of boron in the steel, because it comes from the refractories, and ordinary arc-melted steels can be controlled as closely as this on boron contents.

I am convinced that the present design of vacuum-induction furnaces and vacuum consumable-electrode furnaces is a stopgap measure until these types of steel grow in volume. After all, this equipment is nothing more than scaled-up models of laboratory equipment and represents more or less the first thoughts along these lines. I feel that some combination of arc melting, vacuum degassing, and possibly some form of continuous mould casting, or using a different mould casting set-up to get the type of ingot structure obtained in the consumable electrode furnace, may be the answer in the future if the demand for these high-temperature steels grows to a predictable large volume.

Mr **H. Allsop** (Brown Bayley Steels Ltd): I wish to comment on one or two points in the paper by Child and Harris. With regard to the fatigue test results in Table XI, I should like to know whether the material used for the vacuum-arc re-melts of both basic electric and acid open hearth came from the same casts as those tested as air melts. If not, the change in fatigue strength may not properly represent the effect of vacuum melting, since in the fatigue testing of this type of material at bearing hardness there may be an appreciable cast-to-cast variation.

Has any attempt been made to assess the effect of the degree of vacuum?

It is stated that acid O H material is dirty by vacuum standards, in that it contains 0·02%S. Our experience shows that there is no sulphur reduction by consumable-electrode arc melting, and, if this can be assumed to be so in this instance, then very low sulphur content does not seem to be an essential condition for high fatigue properties. In this connection the generally low level of the basic electric furnace steel should be noted. It may be of interest that neutral O H steel which gives the highest air-melted fatigue strength can be improved by vacuum arc re-melting, although, having a high initial value, the improvement is not so marked as in some other cases.

While I agree with the authors that it is of considerable importance that the earlier history of the steel electrode should still influence the fatigue properties after re-melting, I should like to know whether or not they have any ideas on what it is in the original melting that gives good fatigue properties and seems to persist through the vacuum re-melting, at least under certain conditions.

The further points which I had in mind have been very well dealt with by the last speaker, in rather different terms. The various tensile test results given in the paper for air- and vacuum-melted materials are of interest. In connection with Table XVII in particular, the vacuum-melted tests are from an 8-in. bloom produced from a 20-in. ingot, whereas the air-melted tests are from a 4-in. bloom for which the original ingot size is not given. It is known that the relationship between longitudinal and transverse tests widens, particularly in respect of ductility, as reduction from the ingot increases. The difference in properties is essentially confined to the transverse tests, which may indicate a significant difference in the ingot-to-bloom reduction. Is there anything in this suggestion?

Another factor contributing to this difference could result from the difference in the as-cast macrostructure between vacuum-arc melted and conventional ingots. For example, Fig. 14 shows the macrostructure of a consumable-electrode melt, in this case of high-speed steel, and shows a structure which is most unlikely to be obtained by conventional methods. Such an ingot will show less banding or fibre after forging. It would be of particular interest to me if the diagrams showing the position of test-pieces from the several rotor forgings could be accompanied by the macro-structure showing the flow-lines. To what extent do the authors consider that these factors have an influence on the test results? Mr Harris showed slides which showed variations in elongation from different test positions of air-melted and vacuum-melted materials. In Table XIII it is only in the test-pieces virtually from

the centre of the forgings that there is any significant difference, and even there, in both sets of tests, test-pieces 2 and 4, which presumably bear the same relation to forgings, show lower ductility than 1 and 3, so that this forging effect cannot be ignored.

It is of interest to note that the last speaker made the point that the Kellogg process uses a consumable arc without a vacuum, and the authors themselves say that an improved structure is thereby produced in the resulting ingot. I should like to know whether the fact that they were able to upset such an ingot and make a disc forging in that way might be due to the use of the consumable arc and not necessarily to its use in a vacuum.

I hope that my remarks will not be interpreted as meaning that I do not think that vacuum melting offers advantages. I think that it does, but it is only right that we should try to recognize and evaluate secondary effects rather than accept all of them as due to vacuum melting.

Mr **A. Dunlop** (Foundry Services Ltd): In the first two papers reference is made to the effect of vacuum melting on the properties of the complex Ni–Cr alloys containing such elements as titanium and aluminium. Some years ago we were concerned with alloys of this type, but a little more complex, Ni–Cr–Co with aluminium and molybdenum, and found it quite impossible to forge material of any significant creep strength in these alloys if the ingot was not completely sound. The ingots weighed up to 1 cwt and were melted in air in a high-frequency furnace.

To ensure as sound an ingot as possible we reduced turbulence in pouring to a minimum. A graphite mould was fixed on top of the furnace, and we rolled the assembly over and caused the metal to flow gently into the mould. The design of the ingot mould was arranged to give the best feeding possible. The top of the ingot mould was lined with a red hot refractory lining, and the ingot was fed until we were sure that it was solid by arc-feeding. When we did this we could forge alloys which we could not otherwise forge.

Since then exothermics have been developed and it is easier to ensure good feeding of ingots of that sort. Many hundreds of tons of the above type of alloy are now made in air, using this type of feeding. That goes back to the point made by the last two speakers: we must differentiate between the effect of melting in vacuum and the effect of the method of casting. I made this point in the spring when Mr Child gave a paper at Harrogate, and recalled the Kellogg process. I have seen this technique used in New Jersey and believe that Waspaloy and alloys of that type were first made commercially by that method. In the American paper the figures quoted for Waspaloy casting in air are given. Are they by the Kellogg or the conventional process?

This brings me to a point which has already been made, but which is worth making again. In the slide which Mr Harris showed of the turbine disc, were the air-melted figures from ingots cast in the same way? Were the improved properties due to melting in vacuum or to the method of casting?

I was particularly interested in the comments of Child and Harris on the future of vacuum melting as applied to precision casting. There is a big scope here to improve the quality of precision casting. Diverging slightly from the subject under discussion, great efforts have been made for a long time in the making of precision castings to produce precise pieces of ceramic, and some time later someone says 'We have to pour metal into these moulds', and the metal has been poured in the normal sort of way. If the precision caster is to compete with the forger, he must use vacuum melting and vacuum casting, and probably centrifugal casting in vacuum. One speaker this morning said that he found it difficult to engineer centrifugal casting in vacuum. Equipment is available to do that sort of thing. A supply of vacuum-melted bar stock is available in the UK, and that is a good starting-point for subsequent vacuum melting and casting in small units, as suggested by Child and Harris.

Dr **H. R. Mills** (BISRA): As an engineer, I am interested in what the metallurgist really requires from this sort of plant, and so I have looked through the papers to find what degree of vacuum is really needed. As a result, I am puzzled. I want to refer to the papers presented both this morning, and this afternoon. From the papers this morning it is apparent that a number of people are getting very good results from vacuum casting with a pressure of something like 1 mm Hg, or even between 1 and 10 mm. Also, in this morning's papers I found two or three curves which showed the effect of the degree of vacuum on the removal of gases. In the first one, by Bandel, it seems that improving the vacuum beyond 1 mm Hg scarcely removed any further hydrogen and gave only a little improvement in the oxygen content. There is a similar curve in the Belgian paper, which again shows that about 1 mm Hg gives the best removal of hydrogen which can be expected; by going to a higher degree of vacuum nothing better is obtained. Over a limited range, the paper by Mr Stoll shows the same thing; reducing the pressure from 1·2 to 0·5 mm Hg does not improve the removal of hydrogen.

Coming to the papers this afternoon, Darmara *et al.* quote Samarin as concluding "that there is little reason to melt in vacuum below 3 mm Hg." They do not say that they agree with that, but they quote it as an opinion on the subject. In the paper by Child and Harris, the first paragraph says that down to a few mm Hg "the process could be regarded as one of protective-atmosphere melting rather than a true vacuum-purification process." They suggest that there are many advantages to be gained by going to a greater vacuum than a few mm Hg. On the other hand, Table IV of their paper shows for three different alloy steels the effect of different degrees of vacuum on the gas content, and for two of these steels the minimum amount of oxygen and nitrogen is reached with a pressure of 1 mm Hg, and for the third steel, 0·1 mm. A greater vacuum seems to increase the amount of these residual gases.

It is true that the engineer nowadays can provide high vacuum plant with a fairly good capacity, but the higher the degree of vacuum asked for the more it will cost and the greater will be the problem of maintenance. It seems that there is very little evidence that for removing gases anything better than 1 mm Hg is needed. There may, of course, be other advantages to be gained by going to higher vacua, but it is not clear that much will be gained. I should like to have the views of the authors on that point.

Dr **R. G. Ward** (University of Sheffield): We have been investigating possible ways of deoxidizing vacuum-melted steels by making use of the carbon–oxygen reaction, rather than having to add deoxidants which result in a lot of inclusions in the solidified steel. Theoretically, oxygen can be reduced to 10^{-8}% in a 0·2%C steel under a micron pressure (10^{-6} atm), and this would be an attractively low level of oxidation. This is not approached in our 12-kg induction melts in which the oxygen content drops only to about 10^{-3}%.

We have looked into the course of the carbon–oxygen reaction and find that it occurs in two stages; initially oxygen removal is very rapid with an active carbon monoxide boil which continues until the carbon and oxygen are equivalent to equilibrium with carbon monoxide at a pressure of about 0·1 atm, this is the

ferrostatic pressure on the hearth and suggests that bubble nucleation only occurs on the crucible bottom. The final stage is a very slow desorption of carbon monoxide from the surface which has a negligible effect on the oxygen content of the melt.

The stopping of bubble evolution at an equivalent pressure of 0·1 atm is one of the reasons why extremely low pressures have no particular advantage in decreasing the hydrogen and nitrogen contents. The carbon monoxide boil is responsible for sweeping out much of the dissolved gases, and once the boil subsides the hydrogen and nitrogen contents will decrease very slowly, practically independent of the pressure applied to the bath.

The initial carbon monoxide boil might be speeded slightly by stirring, but no significant lowering of the final oxygen is likely to be obtained (considerable stirring is already present in induction melting). The difficulty is in nucleation rather than mass transport, and in our vacuum melts Mr Bennett has been injecting argon to provide gas nuclei. In this way he has obtained a ten-fold decrease in oxygen content, thus attaining the level of deoxidation required for fully killed ingots without the addition of the deoxidizers normally used. We are hoping to achieve lower oxygen contents approaching the theoretical level in the near future.

Mr **T. B. Biernacki** (Sheepbridge Alloy Castings): I wish to comment on one point only, the removal of volatile or minute quantities of elements. A considerable amount of time has been spent this afternoon in proving that by vacuum-induction melting or vacuum consumable-electrode arc melting some of these elements can be removed almost completely or reduced to very low levels. We use a different process, vacuum degassing of liquid metal in a h f furnace. By this process with the austenitic type of steel some loss of manganese, carbon and silicon is quite noticeable. In the case of lead, with the Nimonic type of alloy we find that with, say, 0·008%Pb we can, by keeping the liquid metal under 1 mm Hg vacuum for about 5 min bring the lead content down to the very low figure of 0·002%. I can safely say that the removal of these undesirable elements does not occur only or necessarily during vacuum melting, but also during vacuum degassing.

Dr **R. Genders,** replying to some points raised in the discussion of the paper by Darmara, Huntington, and Machlin, said: I feel sure that the authors will wish to reply themselves to the points which have been raised. Summing up the contributions as a whole, it seems to be fully realized that we have now in front of us a new subject, the metallurgical chemistry of vacuum melting, on which there is much more to learn, and in which the results achieved up to the present look extremely promising.

Regarding the work at Sheffield mentioned by Dr Ward on reaction between carbon and oxygen and the related NPL work by Mr Rees, this problem is being further investigated at Utica as mentioned in the paper, and there seems to be some factor governing oxygen elimination which is affected by the size of the melt and the refractories. There is hope that the solution can be found and suitably utilized, so that in due course the extraordinary laboratory feats of the NPL in the field of pure metals will be matched by commercial practice.

Mr Child referred to the question of casting and to whether vacuum-induction melted ingots can be produced with a degree of vertical progressive solidification comparable with those made by the vacuum-arc method. I see no reason why that should not be possible, as the solidification of the ingot is due entirely to the form of the temperature gradient during casting, and consequently if the molten metal does not penetrate the ingot deeply, and a continuous vertical gradient is preserved, progressive vertical solidification should occur.

In reply to Mr Post's comment on the data used to show the good effect of cleanliness on transverse properties, the particular fact illustrated has been proved time after time and in very large quantities of commercial material. Transverse properties are mainly governed by the number and form of inclusions and not predominantly by ingot structure as Mr Post suggests. We disagree also on his suggestion that it is difficult to control boron content in induction melting. That it is possible to get boron into alloys in the induction furnace by using certain refractories has been fully realized at Utica, and with the technique which has been developed the boron content can be accurately and positively controlled.

Mr **G. T. Harris,** replying to the discussion on the paper by himself and Mr Child, said: Dr Rodgers referred to the question of what happens to inclusions. Although we do get in the vacuum-arc process a reduction of oxygen content and therefore a diminution of oxide inclusions, I think that the greater effect is that of dispersion. It is found that the large inclusions are now replaced by exceedingly small inclusions, measured in tenths of a thousandth of an inch. This is one of the main assets of the process. He also raised the question of cost, and talked about 2*s* 6*d* and 3*s* 6*d*/lb. Those who are concerned with production know very well that what affects the cost of any alloy is the yield more than the cost of the melting process, and in fact it is not possible to give a cost for vacuum melting until it is known whether or not at the end of it the yield of saleable product is increased. In some cases it is cheaper to vacuum melt than to air melt for that reason.

I agree with a great deal that Mr Post said. One of the great advantages which has 'sold' vacuum melting in the USA is the desire of engineers to have uniformity, not just better properties. There is little doubt that with vacuum melting we can get uniformity in a way which is not possible with the relatively uncontrollable air melting processes. I agree with him that we are only just beginning in the design of furnaces; at present they are scaled-up laboratory furnaces, but one day somebody will put some real engineering behind vacuum melting.

Mr Allsop raised a number of very interesting points. With regard to correlation in the fatigue tests of C–Cr steel, the arc re-melted casts were not from the same cast as the air melts, and therefore the comparison is not exact; but each figure is the mean of several air-melted or several vacuum arc-melted casts, and that has probably balanced out any inequalities.

The sulphur content is a very controversial point. One thing which must be said is that no one has definitely proved whether sulphur is bad or good for bearing life although it does not affect fatigue strength. An inspector who has to see whether or not a high-grade bearing is free from defects cannot be expected to look at something and say 'that is a sulphide,' and so from that point of view all inclusions ought to come out.

Mr Dunlop said something which is absolutely true, namely, that a considerable part of the advantages on the mechanical properties of forgings made by the vacuum arc process arise from the different method of casting, the slow directional solidification in a water-cooled copper mould. We have made that point in the paper. He raised the question of whether or not the flow-lines have an effect on the air and the vacuum forgings. I think the answer is that everything, apart from the method of melting and the method of casting, was identical. These forgings were made in dies, and we can assume that the flow is exactly the same in both

cases. Referring to Table XIII, he points out that test-pieces Nos. 2 and 4 are the sinners in both air- and vacuum-forgings. The slide which I showed was taken from Fig. 13 and gave selected cases. Anybody can make decent mechanical properties at the rim of a turbine or compressor disc, and I was merely focusing attention on the difficulties of getting good properties near the centre.

Dr Mills raised some very interesting questions and wanted to know what vacuum is needed. He should read the BISRA paper, which gives a considerable volume of evidence suggesting that we want something rather better than 1 mm Hg. There are two things to bear in mind. One is the vacuum required, and the other is the volume of gas which we must handle at that pressure, which is quite important.

Mr **G. M. Gill,** replying to the discussion on the BISRA paper, said: I agree with Dr Rodgers that the results obtained from a 1-in. dia. arc-melting process may not be comparable with the larger-scale plants now in operation. However, I would expect that due to the longer time during which the metal is molten in the larger plants, any loss would tend to be greater, given the same level of vacuum. For this reason I find it difficult to explain the low manganese loss quoted by Dr Hobson, particularly at the higher manganese levels. It is possible that the volatilized manganese condenses on the water-cooled mould and is subsequently redissolved by the rising metal. This may also account for the erratic results obtained in the 16-in. dia. ingots.

I would like to thank Mr Rees for drawing attention to the more accurate thermodynamic data available. In reply to his point concerning tin, the erratic behaviour was indeed unexpected and it is thought that this may in part be associated with the sulphur and oxygen contents which under some circumstances can lead to the formation of volatile compounds such as SnS and SnO.

So far no reliable information has been found, to give a vapour pressure of arsenic at steelmaking temperatures, though its vapour pressure at 900° C is considerably in excess of 760 mm. As Dr Capus says, the most likely reason for its failure to be evaporated is its low activity in dilute solution in iron. In the non-ferrous smelting industry iron is in fact used to remove arsenic. We have at this stage carried out no experiments with antimony-bearing steels, but it is intended to include antimony in future projects.

I was most interested in Mr Biernacki's remarks that manganese, silicon, and carbon can be removed during vacuum degassing and in the extremely low lead contents obtained in Nimonics.

CORRESPONDENCE

Mr **E. A. Loria** (Climax Molybdenum Company, Pittsburgh, Pa, USA) wrote: My interest in this paper stems from my former connection with Crucible Steel Company of America where I was concerned with the quality level of vacuum-melted products. The techniques employed in the melting process are certainly the key to this objective. Some of the techniques and problems are described in two articles published early last year.*

Would the authors (Child and Harris) describe what factors can be depended on to determine the quality of vacuum arc-melted steel ingots? It appears that a compromise is necessary in that the ingot with the best surface condition will not necessarily have the least porosity or lowest inclusion count. In melting, it has been suggested that intermediate current ranges should be avoided and that both higher and lower current densities seem to produce the cleanest steels. Also, would the authors describe their best hot-topping practice in melting their largest size ingots?

Can one look at a particular analysis and know that it can be successfully vacuum-arc remelted? Our feeling is that the answer to this hinges on two other problems and these are that the quality of the electrode can vary and that the effects of impurities are great, and are not shown in a simple chemical analysis. Also, one will need to know whether the alloy will have a wide or narrow freezing range; the possibility of two immiscible liquids or a wide liquid–solid range. Then the melting rate creates an additional variable. Small amounts of sulphur have produced radial segregation in both 52100 and A.286. In the case of 52100, sulphur in excess of 50 ppm is not soluble. The increase of inclusions in the solidified ingot is not a linear function and when the sulphur content is increased from 50 ppm to 80 ppm, the amount of inclusions is increased threefold.

Melting steel of a particular type will often give a clue on how to melt a similar analysis. However, this analogy cannot be taken too far. Steels like 52100 and H-11 (UK H-50) are relatively difficult to vacuum-arc melt in the larger mould sizes. It is interesting to note that the authors have melted a 12-in. ingot of H-50 and it would be appreciated if they would comment on the procedures for melting larger-size ingots of both of these steels. Since larger heats are always desired, do the authors feel that an end-point will soon be reached where the molten pool under the arc will become so large that the advantage of quick-freezing found in smaller heats will be minimized or lost entirely? In the case of the 11%Cr steels of the H-46 type, would there not be a good possibility of ingot surface cracking in the larger sizes because of the high hardenability of this steel? The authors' comments on the merits of using cast forged electrodes would be appreciated. The importance of the electrodes being of the correct composition to start with is realized. Have the authors been successful in making additions during remelting? Usually, the resulting product would not be homogeneous but some attempts have been made to add small additions gradually through the space between electrode and side-wall. Also, certain additions have been inserted in a drilled-out area at the bottom of the electrode. In melting a series of vacuum-arc heats from a string of air-melt ingots (electrodes) of a single large air-melt heat of steel, it is necessary to keep a close record of one with respect to the other to avoid any difficulty.

Mr **P. A. Wright** (Capper Pass and Son Ltd) wrote: The apparently anomalous behaviour of tin in these experiments and in those reported by the NPL at the discussion is almost certainly due to the presence of sulphur and/or oxygen, since both stannous oxide and sulphide are much more volatile than tin itself.

Recent determinations of the vapour pressure of SnS place the boiling point at atmospheric pressure at about 1 300° C. This would give a vapour pressure over a 1% solution in iron of 50 mm assuming ideality; the corresponding figure for SnO is probably in the neighbourhood of 0·5 mm.

That the effective species for Sn is more volatile than Pb is shown in Table II. The data presented also show that Cu is not much removed until the Sn has been eliminated; this may simply be due to the relatively lower vapour pressure of Cu, but might also be due to volatilization of a CuS molecule (not to be identified with cupric sulphide); at high temperature, molecules of this kind are quite common. In the experiment on high-sulphur steel the S lost in arc melting is adequate to form SnS

* E. A. Loria: *Blast Furn. Steel Plant*, 1958, vol. 46, pp. 73–78.
E. A. Loria: *Ibid.*, pp. 379–388.

with all the Sn lost; it is unfortunate that the S content of the high Sn steel was not determined.

The high affinity of both arsenic and antimony for iron is well known in tin and lead smelting, where some iron is reduced from the gangue in order to form speiss with arsenic from the base metal. The very low activity of As and Sb in iron thus indicated makes the removal by volatilization most unlikely unless some relatively volatile arsenide of high stability can be formed in the melt; sodium suggests itself for the purpose if it can be introduced.

A second possibility is to remove a number of impurities by forming a dross with Al and then distilling off excess Al, in a manner somewhat similar to the desilverization of lead by addition of Zn and subsequent removal of excess Zn.

Mr **Huntington** wrote in reply to points raised during the discussion as follows: In answer to Dr Rodgers' questions on refractories and the effects on impurities in the melt, it is the writer's opinion that careful refractory preparation and sintering greatly reduces contamination due to refractory particles. There has been no evidence of increased errosion or dirtier heats since we have used low-frequency stirring to ensure thorough mixing. On the other hand the refractories do represent a potential source of impurities such as boron and zirconium, especially in early melts in a new lining and this must be taken into account in making additions of elements when close control is required. Magnesia and alumina refractories also represent a source of oxygen if the carbon and oxygen content of the melt is very low. Under such conditions a gradual pick-up of oxygen in the melt has definitely been noticed. Dr Machlin and Mr Turillon from our Division will shortly publish a paper describing this effect in detail.

With respect to Mr Child's question about slow pouring rates in vacuum, the authors have poured 2 200-lb heats with a range of pouring rates from 50 to 400 lb/min in various types of moulds. Decided improvements have been found in ingot soundness when the rate of pour is closely controlled with respect to the rate of heat extraction from the mould. Although much work remains before the problem is completely solved, the results to date are most encouraging.

Mr Post is correct in observing that design engineers in the USA insist on consistent reproducibility in specific alloys. We have, however, found that they welcome any process which will improve the properties of alloys thus enabling them to design to higher limits. This is provided, of course, that reproducibility still is good. For the record it should be noted that the alloy which was first reclaimed in large quantities for vacuum melting was Waspaloy scrap not 8816. Several million pounds of scrap which otherwise would have been worthless for gas turbine bucket material were reclaimed by vacuum melting during the period 1952 to 1954. The authors mentioned in their paper that they have only recently become active in vacuum-melted steels, for this reason it was not possible to present first-hand data on physical properties. They are happy, therefore, to have the benefit of Mr Post's experience with these data of Crucible Steel Company. It is true that a certain amount of boron is picked up from refractories during vacuum-induction melting. The amount of pick-up, however, varies with the number of heats made in a crucible and the type of metal melted. By experience we have been able to predict very closely the amount of boron to be expected from the refractory for any particular heat and additions of this element are made so that our control is within $\pm$ 8 ppm in the 50 ppm level.

In reply to Mr Dunlop's question on the process used in producing Waspaloy in air, conventional processes were used for all the material reported in the data given. Mr Mills brought up the question of exactly what degree of vacuum is really needed. This depends to a great extent on what alloy is being melted and what is expected to be accomplished in the process. The authors definitely feel that in the production of nickel-base materials a vacuum of 10 μ or better is required in order to produce material with consistent stress rupture properties. We have seen cases in our own furnaces where vacuum difficulties occurred and melts were made at pressures in the range 1–200 μ. These heats never came up to the strict specifications for stress rupture life and had to be scrapped. The reasons for this can be either incomplete deoxidization of the basic charge or the failure to remove volatile impurities below the necessary level. For melting applications where the prime requirement is removal of much, but not all of the dissolved gases, higher pressures can probably be tolerated. However, in order to obtain the full range of benefits offered by induction melting, lower pressures must be employed.

Mr **Harris** and Mr **Child** also replied in writing as follows: Dr Rodgers raised the question of the erosion of refractories in vacuum-induction melting. There are two aspects to this problem, one is chemical and the second mechanical erosion of the refractory. Dealing with the latter, there must always be the danger that during the charging of the furnace with alloys, minor mechanical damage can occur to the walls of the crucible and during the casting operation, mechanical erosion can occur. By careful design of furnace and using the most suitable techniques for fritting refractories, these effects can be minimized. A further precaution is to provide some type of trap for such eroded particles between the crucible and the ingot. This normally takes the form of a bridge in the tundish box which is used for most vacuum-cast ingots. It is important, perhaps, to stress that such inclusions tend to be massive and to float on top of the bath, and hence are more easily separated from the casting stream than inclusions dispersed through the bath, as is common with the deoxidation produced in air-melted steel.

It would seem that little is known as yet about the stability of the various refractories used under vacuum conditions. Little use has been made of the normal commercially pure crucible materials used in air-melting furnaces, that is, commercial magnesite and its various derivative blends. The crucible materials have all been either pure refractory oxides or a blend such as the 70% magnesia, 30% alumina mix used widely in the USA. This material contains a significant clay addition, namely about 5% kaolin, and this can undoubtedly result in a reduction of silica and result in significant silicon contents in the metal being melted. For most applications, this is not serious.

Mr Allsop questions the reason for the dependence of the fatigue properties on the electrode type used for the vacuum-arc process. The work of Frith has shown that the fatigue strength of C–Cr steel is mainly dependent on the inclusion type rather than the number of inclusions present in the steel. This is why the acid open-hearth material, although containing many more inclusions, has a higher fatigue strength as the type of inclusion present has less effect. Presumably, even when the inclusions are reduced in number and in size by the vacuum-arc process, their general effect on fatigue strength remains unaltered.

Dr Ward raises the interesting issue of the difficulty of obtaining equilibrium in the vacuum-induction process, as far as the final oxygen content of the metal is concerned. This is a very important one and the earlier work at the NPL and other research establishments

reduced the oxygen content of the metal to a low level by the use of highly purified hydrogen. Such a technique verges on the impractical when handling large quantities of metal on a production basis. It will be interesting to see whether the concept of facilitating the carbon–oxygen reaction by the use of argon blowing can be made to function usefully on large size melts.

Mr Loria asks what factors control ingot quality in the consumable arc process. The main factor is the melting current and this is determined mainly by three considerations:

(i) the higher the melting current used, the better will be the ingot surface

(ii) higher melting currents, however, will minimize the opportunity for vacuum purification to take place. In general, this is not a very important variable

(iii) the melting rate determines the depth of molten pool and hence influences the freezing characteristics of the ingot. High melting currents are associated with coarser-grained ingots and greater tendencies to segregate. For any steel, choice of melting current is therefore a compromise.

Hot-topping procedures must be related to the freezing range and other physical properties of the steel being melted. In general, however, information concerning these properties is so nebulous that when a fixed procedure is used, the importance of hot topping as a procedure increases with increasing ingot size, as would be expected. As an example, on a 20-in. ingot after the electrode has been nearly consumed, we reduce the melting current from 100% to 30% and hold for 30 or 40 min. We would agree with Mr Loria that the quality of the electrode is a very important variable in consumable-arc melting because the percentage improvement in steel quality on re-melting is not 100%. For this reason, forged electrodes are probably to be preferred for quality, although they represent an expensive alternative to the use of a cast electrode. Provided adequate discards are made from cast electrodes to avoid oxidized pipe etc., these can be used satisfactorily.

As indicated by Mr Loria, sulphur is indeed a very important problem, as sulphur is not removed during consumable-electrode melting and also it is soluble in liquid steel and precipitates on freezing, and so it is not subject to the same dispersion effects as the more refractory inclusions.

The more highly alloyed steels are more difficult to melt in the larger sizes for two reasons. Firstly, they are more subject to segregation and secondly, there is a pronounced tendency for air-hardening qualities to clink during solidification in the water-cooled copper mould. In general, therefore, it is advisable to make these qualities in the smallest acceptable ingot size.

As indicated in our paper, we successfully made 20-in. ingots in the 11% chromium air-hardening steels without clinking, and this effect is minimized by stripping the ingots as hot as possible and annealing them.

While we have made no additions during the consumable arc melting of steels, this practice has of course been used extensively at one time in the melting of titanium alloys and we believe that it could be equally applied to steels. In confirmation of this opinion is the success achieved by the Kellogg process in the USA.

Vacuum casting of steel

By J. Levaux and M. Nepper

SYNOPSIS

The open-hearth steel foundry at Seraing has a Leybolt plant for the vacuum casting of steel. The vacuum casting is operated in two ways, (*a*) large forged ingots are degassed immediately the steel is poured into the ingot moulds, (*b*) small ingots are degassed while pouring the steel from ladle to ladle. Pouring then takes place in air.

The hydrogen content of degassed molten steel is of the order of 2 to 3 $cm^3/100g$; this content shortens the heat-treatment period of the forgings and leads to improved structures, especially in ultrasonic tests. 1654

Equipment

DEGASSING is carried out in three chambers; two chambers have a diameter of 2 900 m and can cast forged ingots up to 42 tons.* The third chamber is 4 m in dia. and can be used either for the casting of ingots of more than 100 tons or for casting by ladle-to-ladle pouring.

The pumping system consists of two sets of pumps, each set divided into three stages; piston-pumps for the first stage reduce the pressure from 760 to 300 mm Hg, Roots pumps for the second and third stages reduce the pressure respectively from 300 to 30 mm Hg and from 30 mm Hg to ultimate vacuum.

Each set of pumps has an exhaustion capacity of 400 l./s at N.T.P.

* Metric tons throughout this paper.

Manuscript received on 18th December, 1958.

Messrs J. Levaux and M. Nepper are respectively manager of the O H steel foundry at Seraing and chief metallurgist of S.A. Cockerill-Ougrée, Seraing.

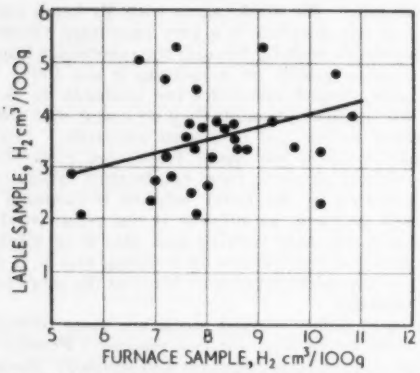


Fig. 1—Ladle-to-ladle pouring, hydrogen contents before and after evacuation

Vacuum casting by pouring from ladle to ladle

This process is used in the casting of small ingots (2·5–4 tons). Generally speaking, small ladles containing electric steel, and operating at the rate of 20 tons per cast are involved.

The steel is degassed during pouring from ladle to ladle. Then, following normal practice, it is air cast. This process permits the study of degassing by taking samples during ingot casting. The sample is obtained by filling a ' pencil-test ' type of mould from a spoon filled directly from the ladle.

Unfortunately, this process is not strictly representative of the best degassing practice obtainable by the vacuum casting of steel. In fact the rate of flow of molten steel during pouring from ladle to ladle is generally faster than when a large forging ingot is poured. For example, pouring from ladle to ladle takes place at a rate of 7 tons/min, while the casting of a large forging ingot is at a rate of 3 tons/min. This unfavourable factor in degassing is, however, partially compensated for by the better dispersion of the stream in ladle-to-ladle casting. This dispersion of the stream assures in principle a better dispersal of molten steel which, as a consequence, facilitates the degassing process. In the case of ladle-to-ladle degassing the amount of hydrogen removed averages 60% although this may reach an average of 70% or more when large forging ingots are being cast.

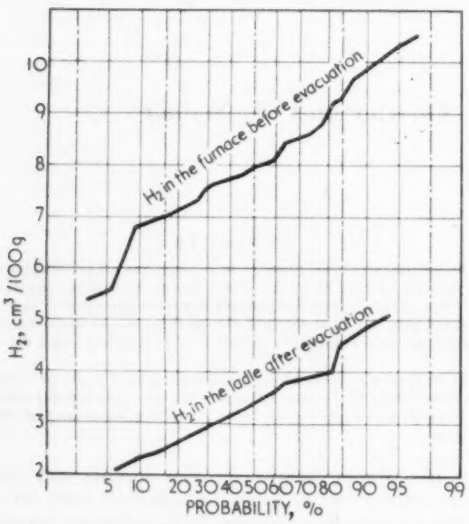


Fig. 2—Ladle-to-ladle pouring, hydrogen contents before and after evacuation plotted as probability curves

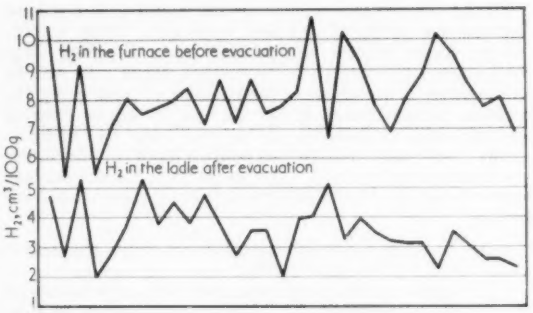


Fig. 3—Ladle-to-ladle pouring, hydrogen contents before and after evacuation plotted chronologically

In the case of ladle-to-ladle pouring the removal of hydrogen is shown in Figs. 1, 2, and 3. The graphs give the results of 31 pourings. Figure 1 shows the hydrogen content of molten steel in the heating pit in relation to the hydrogen content at the time of tapping and before casting. The correlation of these two values indicates that degassing of the order of 60% occurs at tapping with a low hydrogen value of the order of 7 cm³/100 g although the degassing rises to 70% on leaving the furnace with a hydrogen value of 10 cm³/100 g. The same values are given on a probability diagram in Fig. 2 showing that more than 80% of the values of the hydrogen content are below 3 cm³/100 g. In Fig. 3 the values are taken again in chronological order. This graph indicates the increase in the hydrogen content at the furnace, probably due to a seasonal change (humidity of the atmosphere). There is a decreasing hydrogen content after degassing, which corresponds to the progressive control of the process.

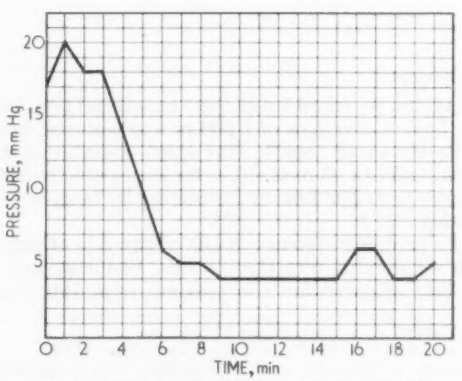


Fig. 4—Degassing curve plotted during casting of a 60-ton ingot

In the early stages of the operation degassing did not exceed 60%, in the later stages it improved progressively until it reached 75%.

This improvement has been achieved by restricting the flow during degassing as well as by a more rigorous maintenance of low pressure.

Vacuum casting into ingot moulds

In this instance degassing takes place in the best possible conditions from the point of view of the steel flow, which scarcely exceeds 3 tons/min.

However, the possibility of dispersing the stream is limited since it is advisable to avoid spreading it at the wall of the ingot mould.

The amount of hydrogen degassed reaches 70% of the content on tapping the O H furnace (about 7 $cm^3/100g$) so that the content of the sample from the feeder-head is about 2 $cm^3/100$ g.

Before pouring, the chamber containing the ingot is evacuated to a few tenths of a mm Hg. When casting begins the pressure rises again sharply to between 13 and 20 mm Hg.

Figure 4 shows an evacuation curve during the casting of a 60-ton ingot. In practice, degassing is regulated by the spreading of the stream. If the stream tends to contract, the rate of exhaustion is increased; if it tends to spread too much, pressure is re-admitted. In the case illustrated in Fig. 4 a pressure of 4 mm Hg was reached after 9 min and this pressure was maintained practically up to the end of the casting of the ingot.

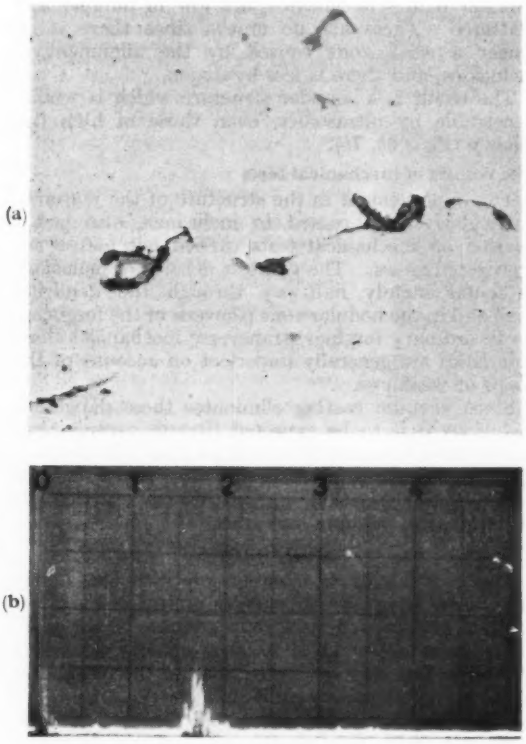


Fig. 5—String of complex oxide inclusions embedded in silicates

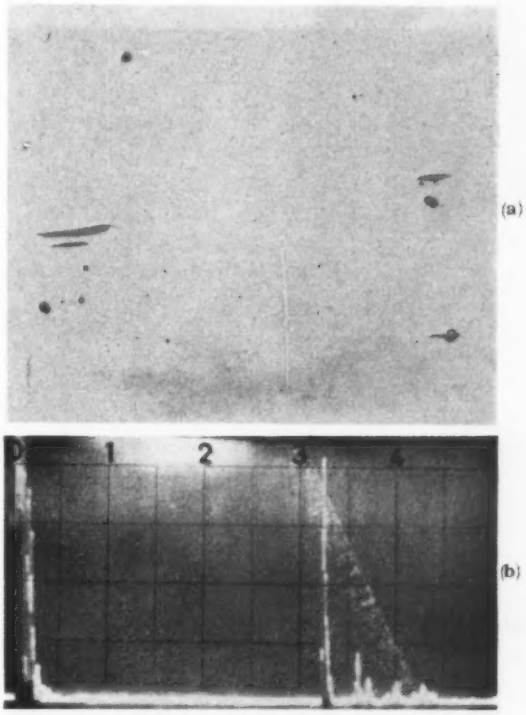


Fig. 6—Sulphide inclusions

Fall in temperature

To obtain the same steel temperature in the pony ladle as in the tundish of the standard process, it is necessary for the steel to leave the furnace at a temperature higher by between 40° and 50° C. In fact, it leaves the furnace after the steel has been analysed, at between 1 630° and 1 660° C, whereas previously these figures were 1 580° and 1 620° C respectively.

In the ladle-to-ladle process, there is a loss of 140° C between the furnace and the pouring of the ingots. This represents about 50° C more than in the standard process.

During degassing in the ingot mould, there is a fall of 90° C between the furnace and the pony ladle and the ingot can be considered as cast at the same temperature as before evacuation. To get the same result in casting in the ingot mould, an overheat of about 50° C in the furnace is necessary.

Application of the Perrin process

The majority of the forgings at Cockerill-Ougrée are made by the Perrin process, i.e. by mixing the steel in the ladle with a desulphurizing and deoxidizing slag. As this process is carried out in the ladle before degassing, the two processes can be combined without any difficulty, the Perrin process for desulphurizing and deoxidizing and the vacuum-casting process to degas when pouring into the ingot mould.

By this method a steel is obtained with the S, O_2, and H_2 contents reduced to a minimum.

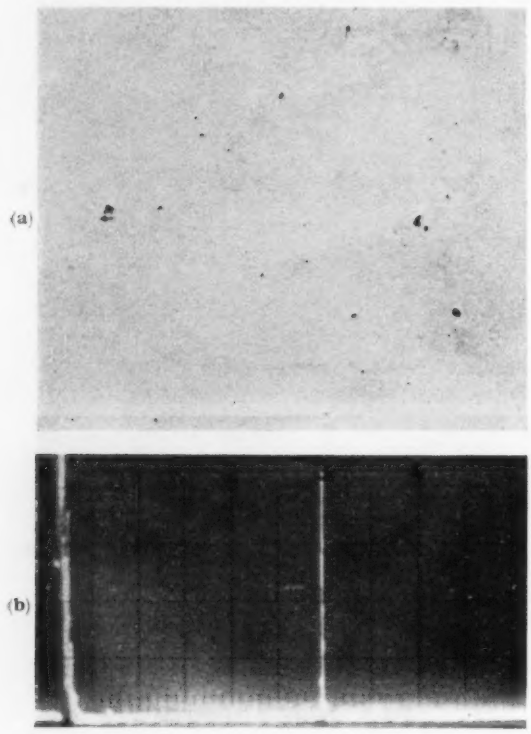


Fig. 7—Widely dispersed oxide and silicate inclusions

Economies

Before the introduction of vacuum casting, forgings had to be subjected to special ' anti-flake ' treatment. In other words, for a 20-ton Ni–Cr steel forging, a treatment to ensure the diffusion of hydrogen was applied to the shaped and uncooled forging. This treatment comprised a complicated cycle lasting between 120 and 240 h. After this treatment the forging was put under slag for slow cooling of variable duration.

Since the introduction of vacuum casting, the ' anti-flake ' treatment is omitted. Only the slag treatment is retained and this takes place immediately after forging. In this way important economies are effected in heat treatment, in the saving of time, and by avoiding the immobilization of the furnaces.

CHARACTERISTICS OF THE FORGINGS OBTAINED

Segregations

Where segregations of sulphur and phosphorus in large forgings are concerned, vacuum casting had little effect.

The segregation of sulphur as shown by Baumann prints remains practically unchanged. The segregation of phosphorus, as revealed by the Stead etch, indicates a primary structure which is slightly finer and more scattered. The dendritic and transition zones are unchanged but in the centre the nodular zone is appreciably finer than in air-cooled ingots.

Inclusions

The vacuum casting of large forged ingots brings about a change in the number and the general form of the inclusions. In air-cooled ingots a large number of complex inclusions of oxides and silicates is encountered.

Figure 5*a* shows an alignment of complex inclusions of oxides embedded in silicates.

In the forgings made from vacuum cast steel, this kind of inclusion is practically eliminated. The quantity of oxidized and silicated inclusions is substantially reduced. Sulphide inclusions (*see* Fig. 6*a*) and small, widely dispersed inclusions of oxides and silicates, of a globular-like shape, (*see* Fig. 7*a*) are found in these forgings.

Results of ultrasonic examination of forgings

In air-cast forgings the inclusions of oxides which we have just described appear in two forms.

Under the action of hydrogen, for example, they cause cracks. Such fissured inclusions are revealed even by low-frequency ultrasonics. It is serious defects of this sort which lead most often to the scrapping of forgings (Fig. 5*b*).

Non-fissured inclusions occur when ' anti-flake ' heat treatment has been carried out. In this case ultrasonics reveal the inclusions less effectively. When the inclusions are relatively numerous and occur in strings, ultrasonics detect them at frequencies of 2–4 MHz. A diffused ultrasonic echo is then obtained. In vacuum-cast forgings the inclusions, whether oxides or silicates, are low in number and scattered. There are no cracks since there is no longer a weak zone caused by the alignment of inclusions, and there is less hydrogen.

The result is a sounder structure which is wholly penetrable by ultrasonics, even those of high frequency (Figs. 6*b*, 7*b*).

The results of mechanical tests

The improvement in the structure of the material, particularly with regard to inclusions, also has a bearing on mechanical tests carried out across the segregated zones. The greatest density of inclusions is found mainly half-way through the dendritic zone and in the nodular zone (the axis of the forgings). As in ordinary forgings, transverse mechanical characteristics are generally imperfect on account of the zones of weakness.

Since vacuum casting eliminates these dangerous inclusions it is to be expected that transverse tests in the zones of segregation will be more satisfactory. This is found quite distinctly for the values of contraction, elongation, and texture tests carried out on forgings of vacuum-cast steel.

CONCLUSIONS

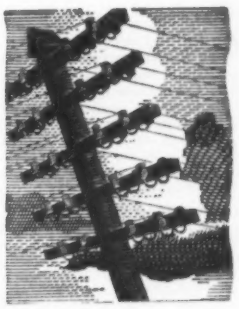
Vacuum casting in conjunction with the Perrin desulphurization process enables a steel of very low sulphur, oxygen, and hydrogen content to be obtained.

The heat-treatment of forgings made from ingots treated in this way can be reduced to the minimum; a simple cooling under slag is sufficient.

The forgings do not flake and the non-metallic inclusions which they contain are few and dispersed in such a way that the penetration of ultrasonics is very easy.

N E W S

Announcements and News of Science and Industry



THE IRON AND STEEL INSTITUTE

Annual General Meeting, 1959

The Annual General Meeting of the Institute will be held in London on **6th and 7th May.** The programme is as follows:

WEDNESDAY, 6th MAY (at the Hoare Memorial Hall, Church House, Great Smith Street, London S.W.1)

10.0–11.0 a.m. Formal business, including presentation of Report of Council and Accounts for 1958; presentation of medals and awards; election of members

11.0–11.45 a.m. Induction of the new President, Mr W. Barr, O.B.E. Presidential Address

12 noon–1.0 p.m. } Technical sessions
2.30–5.0 p.m. }

Technical Session A—**"Recent Applications of Oxygen to Steelmaking"** (in the Hoare Memorial Hall, Church House)

12 noon–1.0 p.m. Introductory review of present-day steelmaking processes, by Dr T. P. Colclough, C.B.E.

2.30–5.30 p.m. Presentation and discussion of the following papers (dates of publication in the *Journal* in parentheses):

"Some investigations on the treatment of molten iron," *by W. J. B. Chater and J. A. Charles* (April 1959)

"The practical aspects of pretreatment processes," *by J. L. Harrison* (April 1959)

"The L–D Process," *by O. Cuscolcca* (to be preprinted)

"Comments on the O.L.P. process," *by B. Trentini, P. Vaysière, and M. Allard* (to be preprinted)

"Further experience on the Kaldo process," *by B. Kalling and F. Johansson*

Technical Session B—**"The Formation of Bainite"** (in the Convocation Hall, Church House)

2.30–5.30 p.m. Presentation and discussion of the following papers:

"The kinetics of bainite formation in a plain carbon steel," *by P. Vasudevan, L. W. Graham, and H. J. Axon* (December 1958)

"The kinetics of the formation of bainite in high-purity iron–carbon alloys," *by S. V. Radcliffe and E. C. Rollason* (January 1959)

"The effect of austenitizing treatment on the formation of lower bainite in a plain carbon steel," *by L. W. Graham and H. J. Axon* (April 1959)

7.0 for 7.30 p.m. **Dinner for Members** at Grosvenor House, Park Lane, London W.1.

THURSDAY, 7th MAY (at the Hoare Memorial Hall, Church House)

Technical Session A (contd.)—**"Recent Applications of Oxygen to Steelmaking"** (at the Hoare Memorial Hall, Church House)

10.0 a.m.–1.0 p.m. Presentation and discussion of the following papers:

"Recent developments in oxygen steelmaking in North America," *by J. M. Gaines* (to be preprinted)

"The use of oxygen in a modified tilting furnace," *by A. Jackson* (September 1958)

"The use of oxygen in a modified tilting furnace: a progress report," *by A. Jackson* (April 1959)

"The use of oxygen in duplex and stationary open-hearth practice," *by O. Pearson* (April 1959)

"The refining of molten pig iron in electric-arc furnaces," *by R. Durrer and G. Heintze* (to be preprinted)

Technical Session C—**"Hydrogen in Steel"** (in the Convocation Hall, Church House)

10.0 a.m.–1.0 p.m. Presentation and discussion of the following papers:

"The diffusion of hydrogen in steel at temperatures of — 78° to 200° C," *by J. D. Hobson* (August 1958)

"Hydrogen in ferrosilicon," *by N. Christensen and K. Gjermundsen* (November 1958)

"The determination of hydrogen in steel by a carrier-gas technique," *by C. E. A. Shanahan and F. Cooke* (December 1958)

"The removal of hydrogen by diffusion from large masses of steel," *by J. D. Hobson* (April 1959)

END OF MEETING

Honorary Member

Mr Arnold Hugo Ingen-Housz, President of The Iron and Steel Institute from 1957 to 1958, has been elected an Honorary Member of the Institute.

A. H. Ingen-Housz

Mr Ingen-Housz, who was born at The Hague, received his technical education at the Technical University of Delft, obtaining a degree in mechanical engineering in 1911. After working with Royal Dutch Shell and the municipality of The Hague, he joined the Royal Netherlands Blast Furnaces and Steelworks Ltd. (Koninklijke Nederlandsche Hoogovens en Staalfabrieken NV) in 1917 as technical assistant to the founder of the company, Mr Wenckebach, in the planning and construction of the IJmuiden plant.

On the death of the founder in 1924, Mr Ingen-Housz became Joint Managing Director of the Company, together with Mr Kessler. When Mr Kessler died in 1945, Mr Ingen-Housz assumed the position of President of the Management Board (Directie), and held this position until his retirement this year.

When he became President of The Iron and Steel Institute in 1957, Mr Ingen-Housz was the first overseas Member to receive this distinction since the late C. P. E. Schneider, who served from 1918 to 1920.

Changes on Council

The following changes on the Council of the Institute will take effect at the Annual General Meeting on 6th May, 1959:

Nominated as President

Mr W. Barr, O.B.E., to succeed Mr C. R. Wheeler, C.B.E.

Honorary Treasurer

Sir Julian Pode to succeed Mr W. Barr

Vice-Presidents

Mr B. Chetwynd Talbot (Chairman and Managing Director, South Durham Steel and Iron Co. Ltd.)

Mr C. H. T. Williams (Managing Director, Park Gate Iron and Steel Co. Ltd.)

Ordinary Members of Council

Major W. R. Brown, D.S.O. (Chairman, Ashmore, Benson, Pease and Co. Ltd.)

Mr T. R. Craig, O.B.E., T.D. (Director, Colvilles Ltd.)

Additional Honorary Members of Council

Dr N. P. Allen, F.R.S. (Superintendent, Metallurgy Division, National Physical Laboratory)

Mr A. Jackson (Technical Adviser on Steelmaking, The United Steel Companies Ltd.)

Medals and Prizes

The Council of the Institute has announced the award of the following medals and prizes:

Bessemer Gold Medal for 1959

To Professor Count Bo Kalling, until recently Director of Research, Stora Kopparbergs Bergslags Aktiebolag, Sweden, in recognition of his distinguished contributions to the physical chemistry of steelmaking and to the development of new processes for the making and treating of iron and steel.

A. Jackson

Sir Robert Hadfield Medal for 1959

To Mr ALBERT JACKSON, Technical Adviser on Steelmaking, The United Steel Companies Ltd., for his notable contributions to metallurgy and metallurgical education, and in particular the advancement of the manufacture of steel from phosphoric pig iron by the open-hearth tilting furnace, culminating in the development of the Ajax oxygen process.

Andrew Carnegie Silver Medal for 1958

To Dr P. VASUDEVAN, Department of Metallurgy, University of Manchester, for a paper on "The kinetics of bainite formation in a plain carbon steel" (*Journal*, 1958, December, p. 386); his co-authors, Dr L. W. Graham and Dr H. J. Axon, were not eligible for an award.

Williams Prize for 1958

To Mr H. C. CHILD, Research Manager, William Jessop and Sons Ltd., for a paper on "Vacuum-melting of steels" (*Journal*, 1958, December, p. 414); his co-author, Mr G. T. Harris, was not eligible for an award.

NEWS OF MEMBERS

Mr **W. E. Alexander** is now technical assistant (mills) to the works manager (Templeborough) at Steel, Peech and Tozer.

Mr **D. R. Baker** has been appointed technical assistant to the works manager (Ickles) at Steel, Peech and Tozer.

Mr **R. Barnaby** has succeeded Mr H. Bull as managing director of Brown-Bayley Steels Ltd.

Mr **G. R. Bell** has left Powder Metallurgy Ltd. to become general manager of the British Division of Wall Colmonoy (Canada) Ltd.

Mr **C. Brown** has obtained a B.Sc. degree in metallurgy at King's College, Newcastle, and is now with C. A. Parsons and Co. Ltd.

Mr **H. R. Brunyee** is now works manager (services) at Steel, Peech and Tozer.

Mr **Harry Bull** has resigned the managing directorship of Brown-Bayley Steels Ltd., but will remain on the board.

Mr **E. L. Burgess** has left the Appleby-Frodingham Steel Company to join the Ensidesa Company at Aviles, Spain, as chief roll designer.

Mr **A. T. Easterbrook** has been elected an Associate Member of the Institute of Fuel.

Mr **S. L. Finch** has been appointed managing director of Weir Foundries Ltd. and a member of the board of Weir-Catton Ltd.

Mr **Vernon Harbord** has retired from active partnership in Riley, Harbord and Law, but will continue his association with the firm as consultant.

Mr **C. H. Hayter** has been appointed works manager (Templeborough) at Steel, Peech and Tozer.

Mr **Langton Highton** has retired from the board of the Workington Iron and Steel Company.

Mr **R. A. Kirby** is now chairman of General Refractories Ltd.

Mr **E. J. McVitie** has been appointed managing director of the Redheugh Iron and Steel Co. (1936) Ltd.

Mr **C. G. Oram**, formerly manager of the central engineering workshops at the Appleby-Frodingham Steel Company, has been appointed to the new position of works manager (production services).

Mr **W. G. Picton** has been appointed President of the Mechanical Handling Engineers Association.

Professor **G. V. Raynor** has been elected a Fellow of the Royal Society.

Mr **T. Sanderson** has been appointed a member of the board of the Workington Iron and Steel Company.

Mr **R. H. Siddons** has joined the Appleby-Frodingham Steel Company, from the United Steel Companies' research and development department, as assistant ironworks engineer.

Mr **G. R. T. Taylor** has been elected president of International Combustion (Holdings) Ltd.

Mr **D. R. Wattleworth**, O.B.E., has retired from the board of the Workington Iron and Steel Company.

Mr **J. G. Widdowson** has resigned his position as managing director of the Neepsend Steel and Tool Corporation Ltd.; he has been elected vice-president of the company.

Obituary

Mr **John Edgar Braham**, B.SC.(ENG.), A.C.G.I., M.I.MECH.E. (*elected* 1944), of Pulborough, in January, 1959.

Mr **Paul Hunt Darrans** (*elected* 1942), of Penistone, Sheffield, on 3rd February, 1959.

Sir **Ashley Skelton Ward** (*elected* 1922), of Sheffield, on 26th March, 1959.

THE INSTITUTE OF METALS

Changes on Council

The following changes on the Council of The Institute of Metals took effect on 14th April:

President

Mr G. L. BAILEY, C.B.E. (Director, British Non-Ferrous Metals Research Association)

Past-President

Marshal of the Royal Air Force the Lord TEDDER, G.C.B.

Vice-Presidents

Professor H. FORD — Mr E. H. JONES — Professor H. O'NEILL

Honorary Treasurer

Mr D. P. C. NEAVE

Ordinary Members of Council

Dr W. O. ALEXANDER — Mr F. DICKINSON

Dr N. P. ALLEN, F.R.S. — Mr L. ROTHERHAM

Medal Awards

The Council of The Institute of Metals has made the following awards of medals:

The Institute of Metals (Platinum) Medal

To Dr L. B. PFEIL, O.B.E., F.R.S. (Director, The Mond Nickel Co. Ltd.) in recognition of his outstanding contributions to non-ferrous metallurgical science and to the non-ferrous metals industries.

L. B. Pfeil

The Rosenhain Medal

To Professor R. W. K. HONEYCOMBE (Professor of Physical Metallurgy, University of Sheffield) in recognition of his outstanding contributions in the field of physical metallurgy.

The W. H. A. Robertson Medal and Premium

To Dr R. B. SIMS (Chief Engineer, Davy and United Engineering Co. Ltd.) for a paper on "Automatic gauge control in rolling mills," published in the *Journal of The Institute of Metals*, 1957–58, vol. 86.

EDUCATION

Waverley Gold Medal

The journal *Research* is sponsoring the Waverley Gold Medal Essay Competition for the seventh year in succession. The competition is designed to encourage and promote improved and more effective reports of scientific and technical work. The Waverley Gold Medal and a prize of £100 will be awarded for the best essay of about 3 000 words describing a new scientific project or practical development, giving an outline of the scientific background, the experimental results, and the potential application of the project or process in industry. The essays will be judged for technical content by specialists in the subject, for clarity of presentation, and for style.

A second prize of £50 will be awarded, and also a special prize for a competitor under the age of 30 on 31st July, 1959.

All entries should be written in English, and should be typewritten, double-spaced, on one side of the paper only; diagrams and photographs may be included. The name, present occupation, technical qualifications, and age of the author should be written on a separate sheet, together with the title of the paper. Entries must reach The Editor of *Research*, 4/5 Bell Yard, London W.C.2, by not later than 31st July, 1959.

Conference on arc welding

A one-day "Joining of Metals" conference on the subject of "*The electric arc in welding*" is being held by the Department of Industrial Metallurgy of the University of Birmingham on Thursday, 25th June. Papers on the following subjects are to be presented and discussed: arc characteristics and their significance in welding, gas absorption from arc atmospheres, the mechanism of metal transfer in the welding arc, heat transfer from arcs, plasma projectors and constricted-arc torches. Applications for enrolment forms should be addressed to

The Secretary,
Department of Industrial Metallurgy,
University of Birmingham,
Edgbaston,
Birmingham 15.

Drop forgers prize competition

The National Association of Drop Forgers and Stampers, of Grove Hill House, 245 Grove Lane, Handsworth, Birmingham 20, is offering prizes of up to £50 for short technical papers on the subject of "Production and processing of forgings." The competition is open to all people resident in Great Britain, and especially to the employees of members and associate members of the association.

Anyone interested in participating in the competition is invited to send to the Technical Officer of the Association the title and a very brief synopsis of his proposed papers.

FORTHCOMING CONFERENCES AND EXHIBITIONS

Pneumatics and hydraulics in industry

A new venture, to exhibit the work of a rapidly expanding industry, is the "Pneumatics and Hydraulics for Industry Exhibition and Convention," which is to be held at the Alexandra Palace, London, from 12th to 16th October. It is being organized by Macfarlane Watson Ltd., 36 Beauchamp Place, London S.W.3, to whom all enquiries should be sent.

During the convention, which will run throughout the exhibition, speakers from the UK, the Continent, and the USA will discuss developments in pneumatics and hydraulics relating to a wide range of industries.

Instrumentation and computation

A joint symposium on "Instrumentation and Computation in Process Development and Plant Design" is being held at Central Hall, Westminster, London S.W.1, from 11th to 13th May. It is organized by the Institution of Chemical Engineers, the Society of Instrument Technology, and the British Computer Society, under the aegis of the British Conference on Automation and Computation.

The symposium will be divided into five sessions, the subjects of which are as follows:

1. The improvement of process efficiency
2. Process control systems

3. Application of on-line computers
4. Design and use of analogue computers
5. The use of computer techniques in large and small companies.

All enquiries should be sent to The Institution of Chemical Engineers, 16 Belgrave Square, London S.W.1.

Quality in industry

The Institution of Production Engineers' the Institution of Engineering Inspection, and the British Productivity Council are collaborating in the organization of a conference on the theme of "Quality in Industry," to be held at the Palace Hotel, Buxton, on 18th and 19th June. The conference will examine from various standpoints the many problems involved in establishing and maintaining standards of quality in industry. Application forms may be obtained from

The Conference Secretary,
The Institution of Production Engineers,
10 Chesterfield Street,
London W.1.

The conference fee will be five guineas.

Dechema Annual Meeting

The Annual Meeting of the Deutsche Gesellschaft für Chemisches Apparatewesen is being held at Frankfurt-am-Main on 21st and 22nd May. It will include a series of lectures reporting progress in technical chemistry and chemical engineering in recent years; there will also be a number of papers on the importance of technical chemistry in research and education.

Further details may be obtained from

Deutsche Gesellschaft für Chemisches Apparatewesen,
Frankfurt(Main) 7, Postfach,
Germany.

Australian Institute of Metals

The 12th Annual Meeting and Conference of the Australian Institute of Metals is being held in Brisbane from 25th to 29th May. In addition to works visits and social functions, there will be a symposium on the properties and preparation of metallic surfaces.

Southern Metals Conference

The Savannah River Chapter of the American Society for Metals will be hosts to the ASM Southern Metals Conference for 1959 in Augusta, Georgia, on 4th to 6th May. The programme of the conference will feature the many new advances in the understanding and use of metals in recent technology, including a discussion of advanced concepts in solid-fuel nuclear power reactors.

Mechanical handling

Arrangements for the next Mechanical Handling Exhibition and Materials Handling Convention are already in hand; it is to be held at Earls Court, London, from 3rd to 13th May, 1960. Full information may be obtained from the Organizer:

H. A. Collman,
Mechanical Handling Exhibition,
Dorset House,
Stamford Street,
London S.E.1.

NEWS OF SCIENCE AND INDUSTRY

New hot mill for Samuel Fox

Work has started on a £1 million scheme to modernize and expand the stainless and alloy steel sheet rolling plant at Samuel Fox and Co. Ltd., Stocksbridge. The development is being carried out in two stages: (1) the widening of the existing cold-rolling mill to produce sheets up to 72 in. wide by the end of this summer, and (2) the installation of a new hot-rolling mill for sheets and light plates up to 72 in. wide, to come into operation by the summer of 1960. When the scheme is completed, the company will be able to supply stainless and alloy steel sheets up to 30 ft long, 6 ft wide, and ¾ in. thick.

The new hot mill is being largely engineered at Stocksbridge, and will incorporate some novel features. As a 2-high mill with an 83-in. barrel length, it will be capable of rolling 5-in. thick slabs into plates and sheets. It can also be set up as a 4-high unit, with 15-in. dia. work rolls; a second set of driving pinions will then be brought into use.

A new walking-beam reheating furnace is being installed to serve the hot mill; equipped with fully automatic control, the withdrawal gear will enable either a slab or semi-rolled plate to be handled by push-button. The discharge table will be fitted with a manipulating table for turning and aligning the plates or sheets before delivery to the mill. Special breast rollers will carry the sheets fully into the pass-line of the small work rolls.

BSA merger

William Jessop and Sons Ltd. and J. J. Saville and Co. Ltd. of Sheffield, together with a smaller subsidiary, Bromley, Fisher and Turton Ltd., comprise the Steel Division of the BSA Group of Companies, and are well known as suppliers of special steels. The two larger companies have both been in existence for many years, Jessops since 1774 and J. J. Saville since the mid-19th century.

After 30 years of common management, it has been decided for reasons of administrative convenience and efficiency that a company known as Jessop-Saville Ltd. should manufacture and sell all products of the BSA Steel Division other than certain small tools. The latter, comprising a range of carbide tips and tipped tools and butt-welded high-speed steel tools, will be manufactured and sold by a company to be known as Jessop-Saville (Small Tools) Ltd.

The entire range of steel products of the three existing companies will continue to be available exactly as before, but through the channel of Jessop-Saville Ltd.

Société de Française de Métallurgie

Professor Paul Bastien has succeeded M Pierre Epron as President of the Société Française de Métallurgie; M de Leiris has been nominated Vice-President, and will succeed Professor Bastien in 1960.

M Eugène Dupuy, Past President and General Secretary of the Société since its foundation, has retired; M Max Dupont has been appointed General Secretary in his place. A new post of Délégué Général has been created, and M André Sourdillon has been appointed to it; he will be concerned especially with relations with other bodies.

New BISF films

Two new films have been produced recently by the British Iron and Steel Federation, intended mainly for foreman training. They are designed to help foremen understand the financial structure of their companies so that they may more fully appreciate management policies and decisions in financial matters; they also help to explain the system by which departmental costs are calculated, since the co-operation of foremen in this field is vital to efficiency.

Money and Steel illustrates the capital structure of a typical company. Animated diagrams are used to show how the company's income pays for raw materials, wages and salaries, services, and other expenses, and how the final trading surplus is allocated to taxation, dividends, and reserves.

Counting the Cost explains how delays in production caused by breakdowns, mishaps, or carelessness affect production costs. The causes of a number of falls in production are examined: a cobble in the mill or an electrical failure in a crane start a chain of events that brings production to a standstill. This is analysed in terms of idle time, loss of yield, and extra heating costs, quite apart from the basic fall in output and cost of repairs.

Both films are obtainable in either 16 mm or 35 mm on free loan from the Federation's Film Library.

Contract for ore-handling plant

Moxey Ltd. of Birmingham have been awarded a contract by the South Durham Steel and Iron Co. Ltd. for the manufacture and installation of ore-handling and grading plant at their West Hartlepool South works.

This plant will handle graded and ungraded ore at the rate of 700 tons/h from railway wagon tippler to a distribution house, whence the ore may be conveyed to the screen house, to the 1 000-ft long stockyard by boom-stacker, or direct to the blast-furnace bunkers. Limestone, coke, and sinter will also be handled by this plant.

Additions to Swinden Laboratories

Pilot-plant models of steel-melting and reheating furnaces are among the equipment installed in an important new addition to the Swinden Laboratories, Rotherham, of The United Steel Companies Ltd.

The new building, 135 ft long by 47 ft wide, has an under-floor walkway tunnel containing gas, water, oil, and steam pipes, which can be tapped to service four major pilot rigs. Take-off points for other services, including electricity, hot air, compressed air, and circulating water are provided at convenient locations.

Three units have already been built: one-fifth scale models of an open-hearth furnace and of a pusher-type reheating furnace, and a 47-ft long flame tunnel. The pilot plants will be used for research investigations into such problems as heat transfer at operating temperatures. Later, it is hoped to study whether unconventional designs can provide an answer to the desirability or otherwise of recirculation in open-hearth furnaces.

Chinese scientific literature

The Lending Library Unit of DSIR has started to collect Chinese scientific literature. About 150 Chinese periodicals are now on regular order and the first batch has arrived at the Library's London premises.

The Lending Library Unit is already noted for its large collection of Russian scientific literature, which is available to research, industrial, and other organizations, through a loans service. The Library also organizes a scheme for the translation of Russian scientific literature, in collaboration with the National Science Foundation in the USA. This may possibly be extended in the future to include scientific literature from China.

Drawdown press order

Davy and United Engineering Co. Ltd. are designing a 3 000-ton hydraulic forging press of 2-column drawdown type, for installation in the Haywood Forge at Halesowen, near Birmingham, of Walter Somers Ltd. Davy-United's contract, valued at £84,000, covers all engineering design, the supply of 100-gal gas-loaded hydraulic balance accumulator, and the provision of the three main crosshead castings. The actual manufacture of the press will be carried out by Walter Somers Ltd. to Davy-United drawings.

A press of drawdown type, as opposed to the conventional pushdown design, offers a number of constructional and operational advantages in forging work, and can be built in both 2-column and 4-column types. As far as is known, the 3 000-ton press for Walter Somers Ltd. will be the largest of its type in the world. It is scheduled to go into operation early in 1960.

ABSTRACTS OF

ASM appointment

Mr Allan Ray Putnam has been appointed managing director of the American Society for Metals. This new post was set up last year by the ASM Board of Trustees after the death of Mr W. H. Eisenman, national secretary and executive head of the Society for 40 years.

The new managing director graduated from the University of Pennsylvania in 1942. After four years in the Army Air Force, he joined the American Electroplaters' Society as business manager, becoming assistant executive secretary in 1949. Mr Putnam is at present president of the Council of Engineering Society Secretaries.

Industrial Publications Received

Chamberlain Industries Ltd. have published a manual on press bending by G. E. Hart.

From Crofts (Engineers) Ltd. come pamphlets on small-power worm reduction gears (Publication 5826) and motorized conveyor pulleys (Publication 5911).

A booklet on oxygen steelmaking has been issued by Head, Wrightson and Co. Ltd., which summarizes the present position with regard to the oxy-Thomas, L–D, and Kaldo processes.

A brochure on the wide range of furnace plants manufactured by Ofenbau-Union GmbH has been published by the company.

Publication 227/2/59 from Fisher and Ludlow Ltd. deals with the Flexiroll conveyor idler system.

LDC electromechanical brakes are the subject of publication ML.87 from Lancashire Dynamo and Crypto Ltd.

Corrigendum

On p. 45 of the advertisement section of the March, 1959, issue, the full title of ISCON should have been given as "The Indian Steelworks Construction Company Limited."

DIARY

4th–6th May—American Society for Metals—Southern Metals Conference—Augusta, Georgia.

6th May—Society of Chemical Industry (Corrosion Group)—Annual General Meeting and Chairman's Address, by Dr S. G. Clarke—14 Belgrave Square, London S.W.1.

6th–7th May—The Iron and Steel Institute—Annual General Meeting—Church House, Great Smith Street, London S.W.1.

6th May—The Iron and Steel Institute—Dinner for Members—Grosvenor House, Park Lane, London W.1.

7th–9th May—Institute of Metals—Residential meeting on "Design and operational aspects of melting furnaces in the non-ferrous metals industry"—Ashmore Hill, Leamington Spa.

7th May—Leeds Metallurgical Society—Annual General Meeting and "Electric melting furnaces," by F. S. Leigh—Chemistry Wing, University of Leeds.

9th May—Swansea and District Metallurgical Society—Annual General Meeting—Central Library, Swansea, 6.30 p.m.

11th–13th May—Institution of Chemical Engineers, Society of Instrument Technology, and British Computer Society—Symposium on Instrumentation and Computation in Process Development and Plant Design—Central Hall, Westminster.

20th May—Cleveland Institution of Engineers—Visit to British Periclase Ltd.—West Hartlepool, 6.30 p.m.

21st–22nd May—Deutsche Gesellschaft für Chemisches Apparatewesen—Annual Meeting—Frankfurt-am-Main.

25th–29th May—Australian Institute of Metals—12th Annual Meeting and Conference—Brisbane.

1st–3rd June—American Association of Spectrographers—10th Annual Symposium on Spectroscopy—Chicago, Ill., U.S.A.

1st–5th June—11th British Electrical Power Convention—Torquay.

BRITISH IRON AND STEEL INDUSTRY TRANSLATION SERVICE

The following translations are now available, in addition to those given on p. 76 of the April, 1959, issue of the *Journal*:

463. Born, K., and W. Koch: "Influence of Aluminium on the Properties of Mild Unalloyed Steels." *Stahl u. Eisen*, 1952, Oct. 9th, pp. 1268–1277. (£1)—Reissue.

599. Nehl, F.: "The Importance of Submicroscopic Precipitation for the Development of High-strength Structural Steels." *Stahl u. Eisen*, 1952, Oct. 9th, pp. 1261–1267. (£5 5*s*. 0*d*.) (For discussion, see translation No. 1222.)

913. Eisenkolb, F.: "Production and Properties of Sintered Stainless Steel." *Stahl u. Eisen*, 1958, Feb. 6th, pp. 141–148. (£5 5*s*. 0*d*.)

942. Daniélou, G.: "Electrical Equipment (for Arc Furnaces)." *L'Aciérie Electrique*, 1957, (Cahiers du Cessid) No. I, Part 2, pp. 1–29. (£8 15*s*. 0*d*.)

986. Zitter, H.: "Examination of Welded and Unwelded Chrome Nickel Steels for Intercrystalline Corrosion." *Arch. Eisenhütt.*, 1957, July, pp. 401–416. (£9 15*s*. 0*d*.)

1073. Czikel, J.: "The Fundamentals of Pouring Technique." *Giesserei-Nachrichten*, 1956, Dec., pp. 5–14. (£4 15*s*. 0*d*.)

1104. Pt. III. Uhlitzsch, H., and G. Radomski: "Use, Manufacture, and Treatment of Alloy Cast Steel Rolls." III—Technology of Making Rolls. *Neue Hütte*, 1958, Aug., pp. 475–482. (£2 10*s*. 0*d*.)

1120. Hasimoto, H. A.: "Aerodynamic Design of the Open-hearth Furnace." I—"Productivity; the use of models." *Tetsu-to-Hagané*, 1956, Oct., pp. 950–955. (£7 15*s*. 0*d*.)

1124. V—"Function of the Air Uptake." *Tetsu-to-Hagané*, 1957, July, pp. 695–699. (£8 10*s*. 0*d*.)

1125. VI—"Function of the Furnace Head." *Tetsu-to-Hagané*, 1957, July, pp. 699–703. (£7)

1126. VII—"Function of the Burner Jet." *Tetsu-to-Hagané*, 1957, Oct., pp. 1094–1098. (£8 15*s*. 0*d*.)

1136. Šárek, J.: "Specific Coke Consumption in Blast Furnaces." *Hutnické Listy*, 1955, Oct., pp. 577–579. (£3 5*s*. 0*d*.)

1139. Koch, H. W.: "Investigations into Vibration in the Vicinity of Forges." *Stahl u. Eisen*, 1958, Sept. 18th, pp. 1320–1326. (£4).

1143. Diestel, P.: "Assessment of the Design and Operation of a Plate Mill on the Basis of Operational Results." *Stahl u. Eisen*, 1958, Oct. 30th, pp. 1536–1546. (£8).

1156. Wiegand, H., and H. Reiner: "Creep Tests in Multi-specimen Machines at Temperatures over 500° C." *Metall*, 1957, May, pp. 357–361; 1958, Sept., pp. 803–810. (£7).

1172. Müller, R., and F. Hollweger: "Practical Experiences with Oil-heated Continuous Furnaces." *Stahl u. Eisen*, 1958, Nov. 13th, pp. 1676–1678. (£2 10*s*. 0*d*.)

1179. Kostkuba, J.: "The Cleaning of Special Steel Slabs." *Hutnik* (Prague), 1956, Dec., pp. 366–371. (£6 5*s*. 0*d*.)

1180. Pt. III. Guthmann, K.: "The Problem of Clean Air, with Special Reference to the Iron and Steel Industry." III—The Removal of Dust from Flue Gases of Arc Furnaces. *Radex Rundschau*, 1958, Nov., (7), pp. 323–347. (£9 5*s*. 0*d*.)

1192. Eberius, E., and W. Kowalski: "Contribution to the Direct Determination of Combined Oxygen in Metals and Metal Oxides." I—Determination of Zinc Oxide in Zinc Dust and Zinc Ashes. *Erzmetall* (*Z. Erz. u. Met.*), 1954, June, pp. 229–234. (£3 5*s*. 0*d*.)

1199. Ginzburg, E. S.: "An Investigation into the Structure and Properties of High-pressure Steam Tubes after Prolonged Operation in Power Plants." The Strength of Metals, ed. N. V. Ageev, Moscow, Akad. Nauk, 1956, pp. 58–66. (£3 5*s*. 0*d*.)

1200. Chizhikov, Yu. M.: "On the Calculation of the Metal Pressure on Rolls." *Stal'*, 1958, May, pp. 428–433. (£5).

1209–1211. "Plain Metal Bearings with Pure Hydrodynamic Lubrication for Roll Necks." *Stahl u. Eisen*, 1958, Dec. 25th,

1209. Sprenger, B.: A. "Bearing Unit with Neck Bush and Tapered Roll-neck." pp. 1853–1861. (£4).

1210. Müllenbach, W.: B. "Roll-neck Bearings with Running Surfaces on the Roll Neck for Large Oil Throughput." pp. 1861–1865. (£3).

1211. Fröhling, J.: C. "Roll-neck Bearings for Hydrodynamic Lubrication." pp. 1805–1867. (£2).

1213. Lessing, H., and H. Malissa: "Investigation into Oxide Inclusions which can be deformed by Hot Rolling and occur in Rimming Steels." *Arch. Eisenhütt.*, 1958, Oct., pp. 627–629. (£3).

1216. Eickler, W.: "New Instruments for the Investigation of Gases and Determination of Their Calorific Value, and for the Control of Furnace Installations." *Gas-Wärme*, 1957, (6), Nov., pp. 348–351. (£2 15*s*. 0*d*.)

1217. Wübbenhorst, H.: "Comparative Data for the Operation of Open-hearth Furnaces." *Radex Rundschau*, 1958, Nov., (7), pp. 348–353. (£2 5*s*. 0*d*.)

1219. Tsukanov, G. E.: "Tube Billet Mill at the Dzerzhinskii Plant." *Stal'*, 1958, Nov., pp. 1012–1017. (£4 5*s*. 0*d*.)

1222. Krekeler, K. A.: "Welding Tests on Steel with a Yield Point Increased by Submicroscopic Inclusions"; with discussion of Papers by Nehl (B.I.S.I. Trans. 599); and Born and Koch (B.I.S.I. Trans. 463). *Stahl u. Eisen*, 1952, Oct. 9th, pp. 1278–1285. (£5 5*s*. 0*d*.)

1233. Thieme, J.: "Fire Cracking of Cast Iron Mill Rolls." *Met. u. Giessereitechn.*, 1952, Jan., pp. 17–18. (£2).

1236. Reerink, W., *et al.*: "Coking Experiments on a Semi-commercial Scale." *Glückauf*, 1958, (3/4), pp. 102–110. (£5 15*s*. 0*d*.)

1237. Echterhoff, H.: "Investigations into the Influence of Water Content, Size Grading and Oil Addition on the Bulk Density of Coking Coal." *Glückauf*, 1958, (3/4), pp. 110–121. (£7 10*s*. 0*d*.)

1246. Kazarnovskii, D. S.: "Ways of Solving the Rail Production Problem." *Stal'*, 1958, Feb., pp. 138–144. (£5 5*s*. 0*d*.)

1274. International Conference of Transportation, October 1956. 1. "Problems of Ore Transport." 2. "Developments in the Construction of Rail Vehicles for European Ironworks." 3. "Speeding up of Turnround of Wagons in Ironworks." Discussion published by the V.D.Eh. (£5 15*s*. 0*d*.)

1285. Pfaffenberger, J.: "The Technology of the Silicon Rectifier." Zenneck, H.: "Experience with Silicon Rectifiers." From book: "Silicon Rectifiers." Siemens-Schuckertwerke A.G. (£6 10*s*. 0*d*.)

A list of the first year's B.I.S.I.T.S. translations is now available, free, on request. Translations are arranged in classified order, with author and subject indexes.

ABSTRACTS OF CURRENT LITERATURE AND BOOK NOTICES

Iron and Steel Manufacture and Related Subjects

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*Abstracts, the reference to which is marked with an asterisk are, or are to be made available as translations.

MINERAL RESOURCES

The Brazilian Manganese Problem. O.H. Leonardos. (*Eng. Min. e Met.*, 1957, **26**, Nov., 271–274). [In Portuguese]. The author describes briefly Mn minerals and ores, and world distribution of Mn and gives Brazilian export figures from 1900 to 1956 (when it was 260 344 t). Details of the deposits in Mato Grosso, Amapá, Bahia, Minas Gerais and other provinces are discussed and the reserves, production, difficulties and progress in each are commented upon. Total reserves are between 75 and 120 million t. In order to conserve Minas Gerais, Espirito Santo, Rio de Janeiro and Sao Paulo ores for internal use, exports will cease on 31st December, 1959. It is hoped that substitution by exports from Mato Grosso and Amapá will avoid inconvenience. The prohibition will continue until home demands are met; it does not include ferro-alloys and other industrial products. (13 references).—P. S.

A Look at Raw Materials. (*Steel*, 1958, **143**, Sept. 15, 152–154). The supply and demand of iron ore, coal, scrap, limestone oxygen and ferro-alloys are reviewed, looking ahead to 1975.—A. G.

Application of Geophysical Prospecting to the Problems of Mining Iron. F. B. Engel and J. Ortega. (*Min. y Met.*, 1958, **18**, Apr., 29–32). [In Spanish]. The authors outline the advantages of geophysical methods and then describe the three types of test of use in Spain: magnetic, resistivity and autopotential. A brief account of the technique used in practice by the geophysicist is then given.—P. S.

ORES—MINING AND TREATMENT

Steep Rock's Hogarth Shaft. (*Min. J.*, 1958, **251**, Oct. 24, 444–445).

Soil Engineering at Steep Rock Iron Mines, Ontario, Canada. R. F. Legget. (*Proc. Inst. Civil Engineers*, 1958, **11**, Oct., 169–188).

Nyasaland Iron Ore on Trial. (*Min. J.*, 1958, **251**, Nov. 7, 504). A shipment of 6 000-t ore from Mindale Hill has been received in Germany.

Iron Ore Supplies for the U.S. Steel Industry. (*Min. J.*, 1958, **251**, Dec. 26, 724). A chart based on three company forecasts is given.

Joy Enters Iron Ore Beneficiating Field with High Tension Separator. (*Iron Steel Eng.*, 1958, **35**, Oct., 155). The characteristics of the new Joy dry separator are described.

Considerations on the Calcination of Siderite. F. Sanchez Gomez. (*Bol. Min. Indust.*, 1958, **37**, Apr., 191–199). [In Spanish]. Particular reference is made to the Vizcayan deposits which contain of the order of 82% siderite. The author discusses the calcination reactions, fuel requirements, theoretical conditions in a vertical, cylindrical furnace for calcination, the effect of excess air, factors affecting furnace practice and variations and deformations in the furnace isotherms.—P. S.

Fluosolids Roasting of Dowa's Yanahara Sulphides. H. Kurushima and R. M. Foley. (*Min. Eng.*, 1958, **10**, Oct., 1057–1061). Roasting of pyrites on Honchu Island for Cu, H_2SO_4 and iron ore is described and illustrated.

Investgations on the Chlorination of Indian Ilmenite. D. P. Kharkar and C. C. Patel. (*J. Sci. Ind. Res.*, 1958, **17B**, Sept., 367–371). Temperature, reaction period, the nature of the carbonaceous reducing agent, ore grain size, use of catalysts and promoters and of briquette binders were examined. With 30% charcoal and 1% CeO_2 with 200 mesh ilmenite all Fe and Ti were chlorinated. at 500° with Cl_2 at 4 l/h. Some O_2 and moisture promotes chlorination. Reduced C favours Fe chlorination and upgrades TiO_2 from 59 to 90%.

Pelletizing before Sintering: Some Experiments with a Disc. D. F. Ball. (*JISI*, 1959, **192**, May, 40–55). [This issue].

New Sintering Plant. (*Brit. Steel.*, 1958, **24**, Oct., 337–338). A brief description and some photographs of the new sintering plant, capable of processing 5 000 t of ore per day for the Youngstown blast furnaces of United States Steel Corporation is given.

Armco Completes Sintering Unit at Ashland Plant. (*Iron Steel Eng.*, 1958, **35**, Oct., 146–152). The construction and operating characteristics of this 2 400-t/day capacity sinter plant are described; the article is illustrated by a flow chart and photographs.

New Iron Ore Sintering Plant Emphasizes Industry Trend. G. J. McManus. (*Iron Age*, 1958, **182**, Sept. 18, 88–89). The new Armco Steel's sintering plant at Ashland, Ky., having an output of 2 400 t per day is described. The growth of sintering capacity is explained in terms of the benefits to the blast furnace.

Self-Fluxing Sinter: Boon For Equipment. (*Steel*, 1958, **143**, Nov. 3, 78–80). The causes and implications of the increasing popularity of self-fluxing sinter are explained. The incorporation of limestone or dolomite in the sinter allows increased capacity and reduced coke consumption on the blast furnace: one reason is that the carbonate is decomposed on the sinter-strand. Limestone suppliers are often prepared to supply ground and dried material.—D. L. C. P.

Producing Sponge Iron in Mexico. (*Iron Coal Trades Rev.*, 1958, **177**, Oct. 10, 858). A note on a process using natural gas offered by the Kellog Co., but developed in Mexico by Hojalata Y. Lamina, SA.

FUEL—PREPARATION, PROPERTIES, AND USES

A General Study of the Factors that Intervene in the Making of Metallurgical Coke. E. Perez Blanco. (*Tecn. Met.*, 1958, **14**, Jan.-Feb., 1–7). [In Spanish]. The need for improved quality cokes from coals not ideal for coking is pointed out. The properties of bituminous coals relative to their suitability for coking, and the physical and operational factors that influence the quality of the coke are discussed. Finally, a review of the properties and tests of the coke is given. (41 references).—P. S.

Errors in the Sampling of Coke. P. Chakraborty, T. C. Tarafdar, A. Ghosal and N. N. Das Gupta. (*J. Sci. Ind. Res.*, 1958, **17B**, Oct., 408–412). A sampling procedure is described and evaluated.

REFRACTORY MATERIALS

Refractories. D. Dixon. (*Inst. Vit. Enamel. Bull.*, 1958, **9**, Oct., 23–26). A brief account of the materials used and their performance.

Refractories. A.S.T.M. Committee C-8. (*A.S.T.M. preprint*, 1958, (21), pp. 11). Tentatives are given for thermal conductivity of castable refractories, for silica refractory brick and for fireclay and high alumina refractory bricks.

Spinel Refractories from Indian Bauxite. J. C. Banerjee and H. B. Chatterjee. (*Refract.*

J., 1958, **34**, Sept., 407–413). Compositions, methods of production and properties are described.

Refractory Magnesia from Sea Water. (*Brit. Eng.*, 1958, **41**, Nov., 157–158). An account of the Hartlepool plant.

Effect of Oxide Additions on Sintering of Magnesia. J. W. Nelson and I. B. Cutler. (*J. Am. Ceram. Soc.*, 1958, **41**, Oct., 406–409). Additions of alkali and alkaline earth oxides, SiO_2 and Al_2O_3; Ti, Zr, Fe, Cr, Ni, Zn, Mo, Pb, Cd and Sn oxides were also used. The densification process is assisted by Ti, Zr, Si, Li, Fe and Zn oxides and an explanation is advanced.

Role of Structural Defects in the Sintering of Alumina and Magnesia. J. T. Jones, P. K. Maitra and I. B. Cutler. (*J. Am. Ceram. Soc.*, 1958, **41**, Sept., 353–357). Mixtures with Ti, Cr, Mn, Fe and Zr oxides were sintered in O, H or N. and the products examined for diffusion effects by X-ray and other methods.

Electron Microscope and Electron Diffraction Studies of Sintering of Magnesite. A. Pande and Rabindar Singh. (*J. Am. Ceram. Soc.*, 1958, **41**, Oct., 394–397).

Casting of Magnesium Oxide in Aqueous Slips. S. D. Stoddard and A. G. Allison. (*Amer. Ceram. Soc. Bull.*, 1958, Sept., 409–413). The slip casting of refractories is described and the behaviour of slips with various grain sizes and the properties of the products are given. Two firing techniques are described and the physical and mechanical properties of the resulting ware are summarized.

The Evaluation of Fireclay Refractories. S. Matthews. (*Refract. J.*, 1958, **34**, Oct., 448–453). Results of 8 standard A.S.T.M. tests on firebricks, refractory mortars, plastics and castables are given. The products submitted were classified and the values presented should serve as a guide for selection or for the drafting of specifications.

Phosphate Bonding of Refractory Compositions. H. D. Sheets, J. F. Bulloff and W. H. Duckworth. (*Refract. J.*, 1958, **34**, Sept., 402–406). Battelle has developed a method of bonding Al_2O_3, ZrO_2, BeO, SiC and Mullite with phosphoric acid or Al phosphate.

Assessment of Ladle Firebrick Quality and Performance. G. M. Workman. (*Trans. Brit. Ceram. Soc.*, 1958, **57**, Sept., 551–572). A statistical examination of data accumulated for 3½ years is presented. Low true porosity was important and life increased with Al_2O_3 content in the range 32–43% with apparent porosity below 15%. Increasingly siliceous bricks of consistently low porosity might ipmrove ladle life further.

Kinetics of Cristobalite Formation from Silicic Acid. A. G. Verduch. (*J. Am. Ceram. Soc.*, 1958, **41**, Nov. 1, 427–432).

How to Make Refractories Behave in Vacuum. (*Steel*, 1958, **143**, Aug. 25, 88–90). The use and behaviour of refractory crucibles in vacuum melting are considered. Selection of the refractory depends on the properties of the metal and impurities.—D. L. C. P.

IRON AND STEEL, GENERAL

Iron and Steel in Belgium. P. van der Rest. (*J. Met.*, 1958, **10**, Oct., 654–655). An outline of the historical development and present position of the Belgian iron and steel industry is presented.

The Russian Steel Industry. (*Iron Age*, 1958, **182**, Sept. 4, 89–104). A review is presented covering such aspects as the reserves, organization technology and expansion plans of the Soviet steel industry together with the economic and social conditions of the labour force.—A. G.

The Integrated Iron and Steel Works. W. B. Wright and W. Eland. (*Chem. Ind.*, 1958, Nov. 22, 1526–1532). A review of the blast furnace and O.H. furnace, by-products and general fuel economy is presented.

Kembla—A Fully Integrated Iron and Steel Works. (*Blast Furn. Steel Plant*, 1958, **46**, Nov., 1164–1186). An illustrated account with plans and descriptions of all departments.

Bochumer Verein. (*Hüttenzeitung*, 1954–1958). Popular articles without technical details, but illustrated, are given as follows: (1954, (3), 2–9). Vacuum steel production. (1955, (1), 8–10), Oxygen steelworks. (1955, (4), 2–3, 23). A new blast-furnace blown in. (1955, (10), 6–11). Modern apparatus for spectrographic analysis controls steel quality. (1956, (3), 2–5). Designing patterns for steel-casting. (1956, (4), 2–8). Vacuum steel has shown improvements. (1956, (6), 2–4). Bochumer Verein steel rings used everywhere in electric machines. (1956, (10/11), 2–3). The largest steel casting (for a rolling mill); also in a special issue (2–15). (1957, (2/3), 2–9). New blast furnace blown in. (1957, (6), 2–4). New Oxygen plant construction. (1957, (10/11), 8–11). Steel production exceeded 10^6 tons. (1957, (12), 10–13). Blast furnace 1 sets up World record. (1957, (12), 14–15). Largest mill stand travels to Austria. (1958, (1), 4–6). A day in the life of a foundryman. (1958, (6), 2–10). 100 Years of wheel casting. (1958, (7), 2–7). Sound absorbers suppress the noise of the engine room and oxygen plant. (1958, (8/9), 8–9). Freight wagons weighed automatically.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

The 5 000-ton/Day Blast Furnace. (*Iron Coal Trades Rev.*, 1958, **177**, Nov. 7, 1103–1106). A report by GIPROMEZ. Charge make-up, ferro-coke, high top pressure and humidified blast, CO_2-air blowing, charging design, removal of pig-iron and slag, furnace construction and the possibilities of automatic control are briefly reviewed.

Augmenting Steel Production at Houston. C. Leinert. (*Blast Fur. Steel Plant.*, 1958, **46**, Sept., 953–956, 965). A description of the results obtained in the 25-ft blast furnace at the Houston plant of Armco Steel Corporation when bedded and screened ore was incorporated with sintered fines. As a result, blast volume was increased by 5%, tonnage by 17%, coke was decreased by more than 5% and flue dust losses by about 80%. Experiments with lime additions to the sinter were successful, and it is intended to work with 15% limestone additions, thus giving a 60% self-fluxing sinter.

Oxygen Enrichment in Iron and Steel Making. (*Metallurgia*, 1958, **58**, Oct., 187, 192). Some notes on the use of oxygen in blast furnace and open-hearth practice.

Oxygen in Blast Furnace Smelting. M. A. Shapovalov. (*Kislorod.*, 1958, **4**, 1–11). Trials at Novo Tula with oxygen-enriched blast are described. Up to 25% enrichment is used for smelting conversion irons and up to 26% for foundry irons. Furnace productivity was raised by 3·5–4% for each per cent of oxygen above 21%. The coke rate remained constant. Up to 31% oxygen blast was used for smelting ferro-alloys. Productivity was raised by 80–90% when smelting FeMn and by 53% for FeSi. Coke rate dropped by 15%. Some economic factors are discussed. When a reducing gas is blown into the hearth simultaneously with the use of oxygen-enriched blast, there is a marked reduction in the coke rate.—R. S.

The Effect of Oxygen-Enriched Blast on Hearth Temperature in the Blast Furnace. V. A. Khromov. (*Kislorod*, 1958, **4**, 11–20). Enrichment of the blast with up to 33·5% oxygen does not change the average hearth temperature which depends on the amount and properties of the slag. Hearth temperature at tuyere level corresponds to the quantity of heat extracted from the furnace by the slag. The actual rise in maximum temperature when going over to oxygen blast is much less than would be expected by calculating the theoretical temperature of combustion. To prevent an increase in maximum temperature and to avoid high temperature at the nose of the tuyere, the rate of blowing must be increased in accordance with the reduction in the specific gravity of the blast/oxygen concentration ratio.—R. S.

Effect of the Kinetics of the Process of Coke Combustion on the Extent of the Oxidising Zone in the Blast Furnace. M. Ya. Ostroukhov. (*Izvest. Akad. Nauk, Otdel. Tekh.*, 1958, (6), 3–6). The oxidizing zone of the blast furnace coincides with the zone of coke circulation. The length of the oxidizing zone is determined by the kinetic energy of the blast since an analysis of the conditions under which the reaction $O_2 + C = CO_2$ occurs shows that it takes place in a region of diffusion. The size of the reducing zone where the reaction $C + CO_2 = 2CO$ is completed in the coke layer depends on chemical kinetic factors (rate of gas filtration, temperature, etc.). The reducing zone has little effect on the dimensions of the oxidizing zone.—R. S.

Kinetics of Reduction of Magnetic Iron Ore at the Transformation Temperatures of Iron. M. I. Kochnev and A. F. Plotnikova. (*Izvest. Akad. Nauk Otdel. Tekn.*, 1958, (4), 118–121). A circulating vacuum apparatus was used for the reduction of magnetite in H_2. The rate was found to fall and rise again over narrow temperature ranges close to the magnetic transformation of iron at 752° C, the β–γ transformation at 906° and at the change in properties at ~820°. These changes are due to the electronic states of the atoms. The work yielded data for choice of processing conditions for ores close to the critical points.

Does Moisture Control Benefit Blast Furnace Air? C. E. Agnew. (*Iron Age*, 1958, **182**, Nov. 6, 114–117). The role of moisture in blast furnace reactions and its effect on operating practice are considered. The fallacies of the dry-blast and controlled-moisture-blast theories for improving operation are explained. Any improvement must allow for maintaining the balance between rate of smelting and rate of stock preparation. Hypothetical examples are given to illustrate the possibilities.

Gas Cleaning, Combined Desulphurizing and Sulphuric Acid Plant. (*Iron Steel*, 1958, **31**, Sept., 454). The process developed by the Appleby-Frodingham Steel Co. in which fluidized hot iron oxide is employed as absorber and regenerator has been operated on a pilot plant scale for 2 years. A full scale plant to be completed in mid-1959 will deal with 32 million cu. ft of gas per day.—A. G.

Nylon Filters for Blast Furnace Sludge. (*Engineering*, 1958, **186**, Nov. 21, 673). Disc filters installed by Richard Thomas and Baldwins Ltd. supplementing Dorr thickeners for water economy use nylon cloths.

Treat Flue-Dust to Recover Iron. J. Mitchell and A. C. Sediachek. (*Iron Age*, 1958, **182**, Sept., 25, 96–97). At the Mystic Blast Furnace of Eastern Gas and Fuel Associates, Mass., a full year's production and use of ferro-coke (incorporating flue dust) has recently been completed. Brickwork of the coke ovens was unaffected and there was a saving in coke at the blast furnace.—A. G.

Pig Iron for the Production of Ductile Iron. H. A. Hunnicutt. (*Bol. A.B.M.*, 1958, **14**, Jan., 19–29). [In Portuguese]. The properties and characteristics of the nodular irons are given and reference is made to the effects of the elements present in the pig iron, and their influence on spheroidal graphite formation. A suitable specification for pig iron is suggested and the problems that these requirements raise are briefly discussed.—P. S.

PRODUCTION OF STEEL

In the October, 1958 Journal, p. 212, col. 1, "Production of Steel." The 5th abstract, "Project for the Establishment of a Small Integrated Steelworks," has inadvertently been separated from the 1st, "The New Paths in Steelmaking." The references should run on.

Sweden Enlarges Output of Quality Steel. (*Times Rev. Indust.*, 1958, **12**, Sept., 87–88). Historical and statistical with notes on the firms producing steel and an account of the sponge iron process and on powder metallurgy.

Durgapur Takes Shape. (*Brit. Steel.*, 1958, **24**, Sept., 284–285). With special reference to the training of technicians in Britain for the project.

Where is Bhilai Now. K. N. Subbaraman. (*Iron Steel Rev.*, 1958, **2**, Aug., 221–222.)

A brief account of the development of the steel city of Bhilai is given.

Recent Developments in Oxygen Steelmaking in North America. J. M. Gaines. (*JISI*, 1959, **192**, May, pp. 55–60). [This issue].

Some Uses of Oxygen in Steelmaking. A. G. Raper and K. H. Hoyle. (*Iron Steel*, 1958, **31**, Oct., 499–503). The main characteristics of the converter process using oxygen-enriched blast or pure oxygen, and of the Kaldo and Rotor processes are outlined.

New Oxygen Plant Starts Operation at U.S. Steel's Gary Plant. (*Iron Steel Eng.*, 1958, **35**, Oct., 163). The new unit, maintained and operated by Linde Division of Union Carbide Corp., will produce 94 000 000 ft³/month of high-purity O_2, which will be used for cutting, scarfing and scrap preparation as well as for metallurgical processes.

The Distribution and Utilization of Oxygen in Integrated Steelworks. D. N. Gwyther. (*Year Book Coke Oven Man. Assoc.*, 1958, 409–420). Supply by cylinder, as liquid, by pipeline or from tonnage plant, and utilization in blast furnaces, O.H. furnaces and converter processes are briefly reviewed and notes on safety added.

Hydrogen in Steel Melting Processes. V. Yavoisky and S. Ray. (*Trans. Indian Inst. Met.*, 1958, **11**, Sept., 47–71). The effects of H_2 on the mechanical properties of steel and its solubility in molten iron, its alloys and the common alloying elements are reviewed. The source of the H_2 is considered in view of recent work in the U.S.S.R. and control in the O.H. and arc furnaces and in the converter is discussed. This reduces, but cannot altogether remove the H_2. Control in the ladle during filling of the mould and during solidification are also described.

Progress in Oxygen-Steel. (*Met. Bull. Supplement*, 1958, Nov. 7, i–x). A brief review is given with accounts of the L.D., Graef-Rotor and Kaldo processes, and with a table of uses and a list of installations.

The Changing Look of Steel Plants. (*Steel*, 1958, **143**, Sept. 15, 156–169). The evolution of the steel plant by 1978 is considered. It is predicted that direct reduction processes, the oxygen convertor and the electric furnace will be increasingly used. Other trends forecast are increased automation, higher thermal efficiency, and greater emphasis on research and the exchange of technical information.—A. G.

The Mysore Iron & Steel Works as a Major Producer of Stainless Steel in India. J. R. Miller. (*Nat. Metallurgical Lab., Council of Sci. & Ind. Res. Jamshedpur*, 1958, 110–115). Possible plans for development are outlined.

Practical Problems in the Manufacture of Alloy Steel. S. C. Biswas. (141–147). A discussion in general terms including cogging, rolling, pickling, annealing and forging. **Oxygen in Foundry Steel Making.** A. K. Gupta. (265–272). Effects on Indian practice of shortage of scrap are considered. In general, the use of oxygen in the electric steel furnace is discussed with estimates of cost. **Furnaces and Equipment Used in the Manufacture and Heat Treatment of Alloy Steels.** R. A. P. Misra. (273–281). A review of types. The crucible furnace, arc, induction and O.H. furnaces, soaking pits, reheating and forging furnaces are very briefly discussed; also normalizing, hardening, tempering, nitriding carburizing and carbonitriding furnaces. **The Molybdenum-Boron Structural Steel.** J. F. Sewell and W. E. Bardgett. (298–305). The composition and properties and method of production of 0·5% Mo–B steel are described and notes on its fabrication and welding are added. **Deoxidation and Inclusion Control for Alloy Steel.** W. Crafts and D. C. Hilty. (148–161). The effects of various elements are summarized and the Fe–O, Fe–FeS, Fe–O–S and Fe (Mn)–S–O systems are considered. Control of initial O_2 content and deoxidation processes are discussed and the effects of deoxidation are noted. (28 refs.). **Progress of Special Steel-Making Processes in Japan.** Y. Ishihara. (172–186). Statistics are shown and basic electric arc steel-making, heat treating, strain-ageing and the effects of nitrogen are reviewed.

New Factory for Sandvik Swedish Steels. (*Met. Treatment*, 1958, **25**, Dec., 513–514). The new Halesowen plant is briefly described mainly in regard to the products manufactured.

The Steel Framework of the New LD Steelworks of Vöest in Linz (Austria). T. Müller. (*Acier-Stahl-Steel*, 1958, **23**, Oct., 432–436). An illustrated account of the construction, with plans.

Huta Lenina. Progress at Poland's Largest Steelworks. (*Brit. Steel.*, 1958, **24**, Oct., 313–316). The development and present capacity and operation of the Huta Lenina steelworks are described, with some photographs of the plant.

Survey of Basic Bessemer Instrumentation. B. O. Smith. (*Iron Steel*, 1958, **31**, Sept., 463–464). The techniques available for temperature measurement and end-point determination are reviewed. Methods based on flame composition or opacity are the most promising means of end-point determination.

New Method of Steel Production at ISCOR. K. Gebhard. (*Demag Nachrichten*, 1958, (151), 20–23). A description of the Graef Rotor process, in use by ISCOR.

Aspects of Tropenas Converter Steel. G. H. Ford. (*Brit. Found.*, 1958, **51**, Aug., 396–398). The author stresses the operational and metallurgical advantages of the side-blown converter for a steel foundry, although melting losses are great, S and P cannot be decreased in the converter and the refractory and labour costs are high. However, the installation cost of the side-blown converter is about one-fourth of any other steel-making unit of equal capacity.—T. G.

LD Produces Alloy Steels in Austria. O. Cuscoleca and K. Rosner. (*J. Met.*, 1958, **10**, Oct., 673–678). A description of the techniques used at Donawitz for blowing plain carbon steels by catching the carbon at the required level is given, using the production of rail steel as an example. Lower Mn contents are obtained by removing part of the slag to prevent reversion. The modifications used for the production of various alloy steels are then described.

Fume Problem of Basic Oxygen Steelmaking Process Solved by Electrostatic Precipitation. (*Ind. Heat.*, 1958, **25**, May, 962, 964). Basic oxygen steel-making produces, per ton of iron, about 34 lbs of dust mostly below 1 micron. A description is given of a horizontal flow plate type electrostatic precipitator installed at the Aliquippa plant of Jones and Laughlin, which will clean 238,000 ft³/min. of gas with an efficiency of 99·95%.—A. G.

European Steelmaking Operations. L. R. Berner. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 12–14). The author outlines some of the differences between European and American steelmaking practice. He refers particularly to the use of mixers and converters in Europe, and differences in charging and teeming practices.—G. F.

European Methods of Acid Steelmaking. P. Herasymenko. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 49–63). European methods of acid steelmaking differ from American practice chiefly in their higher residual Mn contents. The author discusses the physical chemistry of acid steelmaking with particular reference to European methods, and shows that steel with high Mn in the charge can be refined without ore addition and finished without deoxidation addition. Steel-slag reactions are very close to equilibria during the boil. The theory of H_2 distribution between slag and metal is discussed, and the relative merits of lowering H_2 contents by vacuum casting or by casting hollow ingots are outlined.—G. F.

The All-Basic Furnace. J. E. Harrod. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 167–174). The author describes the method of construction and types of refractories used in the 130-t all-basic O.H. furnace at the South Works of U.S. Steel Corp., dealing in particular with the furnace roof. The fuel practice is outlined and production data are given.—G. F.

Design and Operation of Open Hearth Furnaces in Australia in 1957. R. L. Knight. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 266–279). The author first describes and illustrates the development of O.H. furnace design in Australia, and then gives full details of the present-day No. 2 O.H. shop at Port Kembla Works. The design, instrumentation, and operation of the 320-t furnaces are discussed.—G. F.

Quality Considerations in Cold-Metal Charging. R. H. Farr. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 208–212). The author describes the charging and melting procedure in the cold-metal shop at the Worcester works of the U.S. Steel Corp. The important aspects of the quality control programme are emphasized.—G. F.

Open Hearth Operation with High Firing Rates. A. K. Moore. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 26–30). Without increasing furnace size, the Steel Co. of Canada Ltd. has increased its output by combining higher fuel rates with adequate furnace charging times, refractory improvements, and faster furnace repair practices. The author gives details of the basic operations involved and discusses the performance of the No. 3 melting shop, noting the principal changes in the basic factors.—G. F.

Economics of Use of Pig Iron in Cold-Metal Heats. G. J. Schwartz. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956 **39**, 227–231). The author discusses the conditions prevailing at the Alliance Works of American Steel Foundries and considers the important factors which must be taken into account in evaluating the economics of the O.H. furnace charge. These include the price differential between pig iron and scrap, production rates, sulphur content of material charged, increased residual alloy content, and capacity for handling and charging the scrap boxes.—G. F.

Economics of the Use of Pig Iron in Cold-Metal Heats. C. H. Alexander. (*A.I.M.M.E. Proc. O.H. Comm.*, 1956, **39**, 232–233). The author briefly discusses the factors which determine the quantity of pig iron which can be used economically in cold-metal O.H. heats. He considers the use of cast iron scrap in place of pig iron and shows that this depends largely on the permissible residual copper content in the steel.—G. F.

Alloy Steel Production in a Cold-Metal Shop. A. H. Stewart. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 216–217). Brief details are given of the charging, melting, tapping, and teeming practices used in producing alloy steels in the cold-metal O.H. shop at Washburn Wire Co., Rhode Island.—G. F.

New Trends in Firing Practices for Open Hearth Furnaces. J. E. Goodin. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 236–239). The Granite City Steel Co. has carried out an experimental programme in its O.H. shop, using high-pressure natural gas in place of steam as the atomizing agent for the fuel oil. Details are given of the gas compressor and control equipment, and production data are given showing that the use of the high-pressure gas is both efficient and economical.

Advantages of an All-Basic Furnace in a Cold-Metal Shop. L. B. Lindemuth jun. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 230–234). The author outlines the advantages gained in the O.H. shop of Keystone Steel & Wire Co. by the use of basic roof and basic end construction, giving a comparison with the previous general silica construction. Problems peculiar to a cold-metal shop, which need special consideration in order to realize the full benefit of all-basic furnaces, are discussed.—G. F.

Methods Used During Forced Interruptions in Open Hearth Operations. G. A. Ferris. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 24–25). The author summarizes the results of a survey of methods used in U.S.A. and Canada for shutting down basic O.H. furnaces for known or varying lengths of time. Four general methods are outlined.—G. F.

Factors Affecting Heat Time. T. A. Cleary jun. (*A.I.M.M.E., Proc. O.H. Comm.*,

1957, **40**, 32–38). The author describes a study carried out at Youngstown Sheet & Tube Co. to determine the important factors affecting the heat time of an O.H. furnace. Based on records obtained throughout a typical furnace campaign, graphs are drawn showing the effects of checker cleaning, furnace age, time of hot metal addition, and furnace delays.—G. F.

Effects of Improved Combustion Conditions in a Small Cold-Metal Shop. G. M. Hagenberger. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 40–47). The author stresses that, in addition to increased charge weights and firing rates, accurate combustion control can lead to increased production. This can be achieved by more accurate instrumentation, paying particular attention to furnace pressure and the point at which combustion analyses are taken.—G. F.

Prefabricating New Fronts for Open Hearth Furnaces Saves Time and Money. A. W. Schoenebeck. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 129–138). A key element in the expansion programme of the Granite City Steel Co. was the replacement of the fronts of each O.H. furnace. By prefabrication of the fronts before shutting down the furnace, each replacement was made in an average overall time of 58 hr. Details of the method are given.—G. F.

Carbon Removal with Roof-Mounted Oxygen Jets in Open Hearth Furnaces. J. E. Hood. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 33–35). A brief account is given of recent trials by the Steel Co. of Canada Ltd. using the roof-mounted oxygen lance developed by the Steel Co. of Wales. The use of the lance was found to be a practicable method of decarburization, tap-to-tap times being decreased by 45 min. and production rate increased by 2½ t/hr.—G. F.

Physical Characteristics and Chemical Analysis of Foreign Charge Ores, and Their Effect on Open Hearth Production. W. E. Brandt. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 28–30). The author outlines the desirable physical and chemical characteristics of O.H. charge ores. He quotes the properties of Brazilian, Chilean, Dominican, Peruvian, and Cuban ores, and discusses the suitability of each as a charge ore.—G. F.

Progress Report on Basic Construction. A. H. Sommer. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 175–179). This report outlines experience and some results obtained at Keystone Steel Wire Co. with the use of basic brick in the construction of O.H. furnaces. The information covers three campaigns on a furnace with a flat suspended roof and one campaign on a furnace with a fully suspended arched basic roof.—G. F.

Oxidation of Carbon and Mixing of the Metal in Open Hearth Furnaces Using Oxygen. E. V. Chelishchev. (*Kislorod*, 1958, (3), 11–18). A probe for taking three samples simultaneously from three different bath levels is described. The oxidation of carbon occurs in the diffusion region and is limited by the transfer of oxygen through the slag to the reaction zone. The liquid bath becomes extremely heterogeneous when oxygen is used. Oxidation is at a maximum at the slag-metal interface and just beneath the slag. The possibility of reducing the oxygen content of the steel by utilizing the turbulence of the bath to achieve uniform diffusion is explained.

Progress Report on Flat Basic Roof Installation. J. F. Pollock. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 180–183). Details are given of the construction, furnace operation, and maintenance during the first campaign of an O.H. furnace with a flat suspended basic roof at Jones & Laughlin Steel Co. The results obtained with two different types of basic brick are discussed.—G. F.

An Evaluation of Cast Refractory Hot-Top Linings. R. J. Tatousek and A. T. Peters. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 158–162). The authors have compared the performances of cast refractory and brick linings in "C & D" hot-tops fitted to 27½ in. sq. moulds. Although the cast refractory linings lasted longer, they were more difficult and costly to install and eroded more severely. A brick-lined top, reduced in volume by means of increased taper, proved both effective and practicable.—G. F.

Patching an Open Hearth Roof. C. L. Meloy. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 138–143). The author discusses the mechanism of wear of O.H. roof bricks, considering the effects of furnace atmosphere, temperature, and slag conditions. The progressive wear of a roof is illustrated, and the effect of hot-patching practices on campaign life is studied.—G. F.

A New Approach to Open Hearth Maintenance. E. W. Hunziker and M. E. Strate. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 110–128). Reconstruction of O.H. furnaces at the Geneva plant of United States Steel Corp. has been carried out by pre-erection of a complete furnace framework outside the melting shop followed by final location of the structure by means of transfer cars and overhead crane. After experience of this method on several furnaces, one furnace has also been pre-erected with the refractories installed. The method is described in detail and the authors discuss its potentialities in the O.H. shop of the future.—G. F.

Bottom Construction and Maintenance. G. Ferris. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 100–101). The method of installing O.H. furnace bottoms at the Dearborn Works of Ford Motor Co., and the maintenance procedure adopted, are briefly outlined.—G. F.

Bottom Construction and Maintenance—Gun-Placing Tapholes. A. M. Kroner. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 101–102). The O.H. furnace tapholes at Inland Steel Co. are placed by means of a refractory gun. This method has increased taphole life and decreased taphole delays. Brief details are given.—G. F.

Maintenance of Open Hearth Bottoms. H. M. Kraner. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 95–100). The author discusses the importance of slag chemistry in O.H. bottom performance, and considers the characteristics of various bottom materials. The method of bottom construction at Bethlehem Steel Co. is described.—G. F.

Mechanical Aids to Open Hearth Repairs. M. H. Weir. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 226–229). The author gives details of some of the mechanical aids used at the Houston Division of Armco Steel Corp. to speed furnace repairs. They include machines for removing brick debris from the furnace and casting pit, for breaking and removing slag from the slag pocket, and for transporting the palletized brick shipments.—G. F.

Contribution of Bath Temperature Control to Improved Open Hearth Production Rates. W. J. Flynn. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 245–251). The author describes the development of the spoon immersion thermocouple for measuring metal temperatures, and gives details of its present use in the Gary Works of United States Steel Corp. Experience indicates that the assembly can be used as a successful and economical method of maintaining close control of bath temperature.—G. F.

Influence of Open Hearth Combustion Practice on Rates of Heat Transfer as Determined by Use of the Hot-Model Technique. J. H. Richards. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 253–266). The author describes the hot-model O.H. furnace of U.S. Steel Corp., and compares the heat distribution in the model with that expected in a commercial furnace. The effects of ten combustion variables on the rates of heat transfer to the hearth and checkers and on fuel efficiency are evaluated, and the magnitude and importance of each of the significant effects are discussed separately.—G. F.

Use of Natural Gas to Atomize Heavy Oil in the Acid Open Hearth. R. J. Sherlock. (*A.I.M.M.E. Proc. O.H. Comm.*, 1956, **39**, 37–39). The author outlines operating experiences at the Union Steel Castings Div. of the Blaw-Knox Co., where heavy fuel oil is atomized by means of natural gas in firing a 35-t acid O.H. furnace. Some cost details are given.—G. F.

Effect of Banding and Oil Impregnation of Nozzles on Pouring Performances. A. Sontz and R. N. Ames. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 147–155). The authors have studied the possibilities of minimizing the effects of thermal shock on the performance of ladle nozzles, firstly by binding them tightly with steel bands, and secondly by impregnating them with oil. Laboratory and service trials indicate that only the first method is efficacious.—G. F.

Use and Economies of Basic Runners. A. R. Edwards. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 219–225). The Keystone Steel & Wire Co. has found that rammed basic runners and tapping spouts are far superior, in service and overall cost, to the conventional brick-lined runners and spouts. The method of construction is described and illustrated, and performance details are given.—G. F.

Analysis of Molten Steel Flow Rates Through Refractory Nozzles. C. H. Martin and H. L. Taylor. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 84–92). The authors have carried out a detailed analysis of weight-flow rate data taken during ingot pouring, using three nozzle types and three sizes. Nozzle erosion and variations in flow rate occur with both magnesite and fireclay nozzles, but to a lesser extent with the former. In both types, erosion is directly proportional to time so that analytical methods can be used to compute weight-flow rates as a function of time. The basic physical relationships governing flow rates are discussed.—G. F.

Liquid Steel Streams in Air. B. M. Larsen and J. B. Wagstaff. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 97–106). The authors discuss the occurrence and mechanism of oxygen absorption by liquid steel streams, dealing separately with the tapping stream from the furnace and the teeming stream from the ladle. A study of teeming streams using a water model is described and it is shown that the normal roughness of such streams is related to the drag effect of the surface of the nozzle bore.—G. F.

Experiments with Fuel-Fired Jet Atomizing Fuel-Oil Burners. W. Wood. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 241–244). The author gives details of the Linde fuel-fired jet atomizing burner, and describes its use in experiments carried out at Youngstown Sheet & Tube Co. The results indicate the possibilities of improving both combustion and production through improvements in burner performance.—G. F.

Current Concepts of Open Hearth Slag Control. M. W. Lightner. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 304–314). The author discusses the development of slag control methods from the immediate pre-war years to the present-day. Current concepts of slag control are considered, and attention is given to the effect of charge materials, flush slag practice, and sulphur control—G. F.

The Oxidation of Internal Plates in Chemically Bonded Basic Roof Bricks. W. S. Treffner. (*Radex-Rundschau*, 1958, (5), 203–211). [In English and German]. The cause of the wide oxidation zone along the internal plates in unburned, originally chemically bonded, steel-clad magnesite-chrome bricks after use in an O.H. furnace was studied. The microstructure was examined and characteristics of the steel plate area discussed as well as the oxidation mechanism involved.

Use of Basic Refractories for Open Hearth Roofs and Checkers. C. W. Cravens. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 191–200). The author describes a number of trials at Republic Steel Corp. of basic refractories used in O.H. furnace roofs and checkers, paying particular attention to the use of "Electrocart" basic brick in the roof in a "zebra" construction. The indications are that a full roof of this type of brick would be economically sound.—G. F.

Progress Report on All-Basic Roofs at Laclede Steel Company. L. D. Yager. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 183–184). Brief details are given of experience gained with flat suspended basic roofs in the O.H. shop. Production has been

increased by 15% with no change in fuel consumption.—G. F.

Optimum Operating Conditions and Design for Maximum Roof Life. L. D. Yager. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 219–220). The four 170-t basic O.H. furnaces at the Alton plant of Laclade Steel Co., Ill., are fired with oil and either high-pressure gas or steam. The author outlines the furnace design and roof construction, and discusses the importance factors of design and operation affecting roof life.—G. F.

Optimum Operating Conditions and Design for Maximum Roof Life. J. L. Jennings. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 221–224). The author describes the design of the three 80-t and one 60-t basic O.H. furnaces at General Steel Castings Corp., Ill., and outlines the maintenance programme. The factors affecting roof life are considered.

Applications of Hot-Model Technique to Studies of Factors that Affect Temperature Distribution Along an Open Hearth Roof. J. H. Richards. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 81–91). The author describes the "hot-model" O.H. furnace at United States Steel Corp., and discusses the experimental work on the effect of the following factors on roof temperature distribution: fuel temperature; steam pressure and superheat; maximum roof temperature; steam-fuel ratio; furnace pressure; air preheat; burner angle and elevation; and air–fuel ratio.—G. F.

Effect of Furnace Dimensions and Firing Rates on Furnace and Roof Performance. W. S. Debenham. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 78–80). The author examines some of the factors which affect O.H. furnace roof life. He concludes that the height of the roof above the bath is an important factor, and suggests that trials designed to determine the optimum roof height would be worthwhile.—G. F.

General Use of Basic Refractories in European Open Hearth Practice. A. H. Sommer. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 57–65). The author gives a general review of basic refractory practice in Europe, describing three O.H. basic roof installations and comparing their performance and method of construction with American practice. The more extended use of basic bricks in various parts of O.H. furnaces at Keystone Steel & Wire Co. is also described.—G. F.

Basic Refractories for Checker Service. C. C. Benton. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 66–72). A test run of basic checkers in an O.H. furnace at Algoma Steel Corp. is reviewed, and further experience on the furnace and subsequent installations on other furnaces are described. Information on the suitability of various types of basic brick is given, together with operating data showing the improvement in furnace performance.—G. F.

Special Roof Brick Trials. B. L. Dorsey. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 92–94). The author describes trials carried out at Jones & Laughin Steel Corp. of the "skunk" roof construction, in which two key courses of metal-clad magnesite–chrome bricks are spaced in the silica roof at 2 ft intervals from the skewback. The trials indicate an increase in roof life of 14%.—G. F.

Progress in the Use of Basic Checkers. A. H. Gommer. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 72–76). The author describes the results of two major O.H. campaigns using basic-capped checkers at Keystone Steel & Wire Corp. It is concluded that, whilst 6–10 courses of basic brick are sufficient with a conventional furnace, the all-basic furnace should have basic refractories beyond the slag pocket and fantail area.—G. F.

Progress Report on Flat Basic Open Hearth Roof at Inland Steel Company. P. W. Nutting. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 184–190). The author describes and illustrates the construction of the first flat-basic roof installed at Inland Steel Co. The furnace operation is outlined and production and cost data are given.—G. F.

Dual Roof-Temperature Control. R. A. Lambert. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 279–282). All the furnaces in the No. 4 O.H. shop of Jones & Laughlin Steel Corp. are equipped with two-point roof temperature control, one primary measuring element being located near each end of the roof. There elements ("Rayotubes") consist of a radiation pyrometer sighted on a closed-end target block. The author describes the performance of these installations, and gives details of costs and maintenance.—G. F.

The Influence of Porosity on Silica Roof Performance. H. R. Lahr and C. W. Hardy. (*Trans. Brit. Ceram. Soc.*, 1958, **57**, May, 271–287). Differences in Al_2O_3 content masked porosity effects. Special bricks of uniform composition and varying porosity were obtained and tested in O.H. roofs. Porosity in the range 15–30% had a small adverse effect on performance.

Expansion Allowance in Basic Open Hearth Port Ends. L. L. Wells jun. and T. P. Greaney. (*J. Met.*, 1958, **10**, Apr., 277–280). The authors describe their experience with suspended basic construction in O.H. furnace port ends. Some early failures are discussed and the methods of overcoming them are outlined. The importance of proper expansion allowance, correct suspension, and good sealing of joints, is emphasized.—G. F.

Firing Practice: Natural Gas Replaces Steam. J. E. Goodin and V. B. Thompson. (*J. Met.*, 1958, **10**, Apr., 272–273). The authors describe the use of natural gas in place of steam for atomizing liquid fuel at Granite City Steel Co. and Empire-Reeves Steel Corp. respectively. At both plants the result has been better overall operation and higher production.—G. F.

Methods of Use and Benefits Derived From Automatic Reversal. L. R. Berner. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 268–271). The author analyses the advantages and disadvantages of automatic reversal in O.H. furnace practice, referring particularly to experience at Inland Steel Co. The factors influencing the choice of method of applying automatic reversal are indicated.

The Behavior of Chromium in Slag-Metal Systems Under Reducing Conditions. C. W. McCoy and W. O. Philbrook. (*Trans. Met. Soc. A.I.M.M.E.*, 1958, **212**, Apr., 226–235). The authors have investigated the reactions of Cr in liquid carbon-saturated iron and lime–silica–alumina slags under strongly reducing conditions. The reduction of chromous oxide from the slag behaves as a first-order process, the rate being substantially independent of temperature in the range 1500–1650° C and of slag basicity in the range 0·6–2·5 lime–silica ratio. The equilibrium distribution ratio of Cr is evaluated.—G. F.

Open Hearth Fuel Atomization with a Reaction-Type Jet Burner. G. W. Hinds and A. L. Hodge. (*Ind. Heat.*, 1958, **25**, July, 1380, 1382, 1384). A burner using a gas jet to atomize liquid fuel is described.

Combustion of Liquid Fuel in the Open Hearth Furnace. H. V. Flagg. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 248–260). The author gives a simple analysis of the O.H. combustion system, presenting the various factors entering into the development of a melting flame from liquid fuel. He discusses the definite functions of the various parts of the system and emphasizes some of the general principles which do not seem to be generally understood.—G. F.

Automatic Steam-Fuel Ratio Control. W. H. Kahl. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 273–277). The author gives a short history of the experience of steam atomization at the Inland Steel Co., and describes the automatic steam-fuel ratio control system installed in the No. 3 melting shop. The advantages of the system and the benefits obtained are outlined.—G. F.

Continuous Waste-Gas Analysis and Control in the Open Hearth. F. S. Swaney. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 260–265). The author discusses the advantages of fuel-air ratio control in O.H. furnace operation, and describes the development of the control system adopted by Jones & Laughlin Steel Corp. This is based on continuous analysis of the waste gas for oxygen content, using a paramagnetic analyser. The overall benefits are outlined.—G. F.

Quality Incentive for Open Hearth Melters. J. R. Behrman. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 15–19). As a means of increasing the production of ingots capable of meeting the more rigid specifications of strip-mill applications, the Alan Wood Steel Co. (Pennsylvania) has introduced an incentive system for O.H. melters, incorporating both a quality bonus and a tonnage bonus. Details of the system are given, and production figures are quoted showing the improvement obtained.

Effect of Melting Practice on Hydrogen Content of Steel. H. Epstein. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 118–130). The author discusses the aspects of melting practice which affects the H_2 content of steels made in acid and basic O.H. furnaces and in basic electric furnaces. Moisture introduced into the furnace is the main source of H_2, and data are given showing that the rate of H_2 absorption is influenced by the moisture content of the furnace atmosphere and of the bath additions, and by the type of slag. The rate of H_2 removal is proportional to the rate of CO evolution during the boil.—G. F.

Statistical Quality-Control Methods in Open Hearth Production and Their Effect on Tonnage. A. V. Lang. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 21–26). The author describes examples of the application of correlation analysis, control charts, and long-term trend charts in O.H. production, dealing primarily with operating problems.—G. F.

Effect of Ladle Deoxidation on Steel Cleanliness. C. R. Funk. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 242–245). The author discusses the sources of inclusions in steel and emphasizes the important part played by ladle deoxidation procedure. He shows that correct deoxidation procedure depends very largely on the particular properties required in the steel.—G. F.

Machine Adds Ferro-Manganese to the Ladle for Open Hearth Steelmaking Economy. (*Ind. Heat.*, 1958, **25**, May, 977–978). The machine consisting of a hopper, hopper loader, vibrating feeder and chute is stated to deliver up to 31·5 lbs of Fe–Mn per t of ingots with improved Mn recovery.—A. G.

Desulphurization of Metallurgical Blast Cupola Metal for Use in Open Hearth. W. S. Webb. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 212–218). The metallurgical blast cupola (M.B.C.) differs from the conventional cupola in that it melts continuously for longer periods, uses up to 100% steel scrap, and produces hot metal of blast furnace quality. The author describes the M.B.C. practice at Phoenix Iron & Steel Co., Harrisburg, Pa., dealing particularly with the slag control necessary for desulphurization within the cupola, and outlines the satisfactory results obtained with M.B.C. iron in O.H. furnaces.

Steel Scrap Specifications for Duplexing Cupola White Iron. R. H. Greenlee. (*Mod. Castings*, 1958, **33**, June, 72–74). The benefits resulting from a programme of rigid specifications for the purchase of scrap are listed. These include uniformity of melting conditions, reduced Si and Mn losses and minimum annealing times.—A. G.

Charging of an Arc Furnace with Long Scrap by Means of a Roller Table. A. E. Väisänen. (*Radex–Rundschau*, 1958, (**5**), 243–245). The author gives some details on the design, performance and lining of a Kennerfeldt arc furnace of 3·5-t capacity and describes a roller table for charging whole railway rails into the furnace. By using this device he obtained increase in productivity and saving in power, lining costs and manpower.—T. G.

Supply-Voltage and Current Variations Produced by a 60-Ton 3-Phase Electric Arc Furnace. B. C. Robinson and A. I. Winder. (*Proc. I.E.E.*, 1958, **105A**, Aug., 305–318, discussion 318–324).

Manufacture of Leaded Steel. W. D. Smith. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 12–22). The author describes the practices now in use for the manufacture of leaded steels at Jones & Laughlin Steel Corp. The gun assembly used for making the lead additions and the equipment necessary for fume

removal are described, and details are given of the teeming and blooming mill practices. Figures are quoted showing the level of lead recovery and the extent of segregation in the ingot. The methods of testing and inspection are also described.—G. F.

On the Technology of Bottom Pouring of Killed Steel Ingots. I. Žádný. (*Hutník*, 1958, **8**, (5), 148–150). [In Czech]. The practice of discontinuous pouring is discussed. In the case of rail steels the improvement in steel quality obtained in this way is not ascribable to a reduction in the contraction cavity in the ingot but to a better quality of steel, due to improvements in the structure arising from the rapid convection currents occurring with interrupted casting.—P. F.

The Production of Magnesium Cast Iron Ingot Moulds in Chill Moulds. G. A. Pisarenko, S. G. Guterman, Ya. I. Aizikovich and P. D. Elokhov. (*Stal'*, 1958, (7), 668–672). The properties of chill cast and sand cast moulds are also compared.

Effect of Ingot Thickness on the Quality of Rimmed Steel. W. H. Mayo, S. B. Prellwitz, and M. B. Jacobs. (*A.I.M.M.E., Proc. O.H. Comm.*, 1956, **39**, 146–165). Data from a number of plants are presented to show the centre sulphur segregation pattern in slabs and sheets rolled from ingots varying in thickness from 22 in. to 46 in. A general pattern is observed which can be related to ingot thickness and also to average sulphur content.—G. F.

Continuous Casting of Steel. V. Yavoisky and P. K. Sen. (*Trans. Indian Inst. Met.*, 1958, **11**, June, 27–56). A discussion of the advantages of the process and a general description of the machines used are given. Thermal losses, effects of mode of crystallization and defects appearing and their remedies are also considered.

Continuous Casting of Steel. (*Machinery*, 1958, **92**, June 20, 1456). A brief account of the Low Moor experimental installation is given.

Continuous Casting Plant: New 8-Strand Machine for Italian Steelworks. (*Iron Steel*, 1958, **31**, Apr., 130–131). An 8-strand continuous casting plant is being built by Demag, in co-operation with Mannesmann and Bohler, for the Terni Società in Italy. The machine is designed to cast 110 or 140 mm sq. sections, ultimately with a capacity of 60–70 t/h. Brief details are given of the plant design.

Use of Models in the Continuous Casting Process. K. I. Afanas'eva and G. P. Ivantsov. (*Stal'*, 1958, (7), 599–604). Investigation of the hydrodynamics of metal flow by means of models is described and suggestions for improvements of continuous casting installations are made.

Review of Paper on Continuous Casting of Three Types of Low-Carbon Steel. F. G. Jaicks, L. E. Kraay, and M. Tenenbaum. (*A.I.M.M.E., Proc. O.H. Comm.*, 1957, **40**, 67–79). The Inland Steel Co.'s continuous casting studies using the Atlas plant involved the casting of 24 × 6¾ in. slabs in rimming, semi-killed and killed low-carbon steels. The author describes the plant and general sequence of operations in casting the three types, and then discusses particularly the commercial possibilities of casting slabs for the manufacture of hot-rolled and cold-rolled sheets. He takes into account slab width, casting speed, and plant availability and considers the co-ordination of the plant with different types of steelmaking unit.—G. F.

The Comparison of the Results of the Working of Open Hearth Furnaces with Chromite–Magnesite and Silica Vaults. S. Tochowicz and K. Levittoux. (*Hutnik*, 1958, **25**, March, 93–99). [In Polish]. The authors discuss the technical and economic advantages of chromite–magnesite vaults in comparison with silica vaults in Polish steel works.

Application of Martinite to the Repair of Open Hearth Furnace Bottoms. F. Z. Dolkart, P. P. Semenenko, S. G. Slesarev, and I. G. Fadeev. (*Stal'*, 1958, (7), 604–606).

On the Distribution of Oxygen in Molten Steel during Refining. K. Nagami, M. Koya, and Y. Nagano. (**Sumit. Met.*, 1958, **10**, Jan., 1–4). In the O.H. furnace, the oxygen content in steel at the intake side decreases with time after reversal; at the exhaust side it increases. That near the middle door is nearest the mean value, and this door should be used for taking samples.—K. E. J.

Revision of Geller–Dicke Equilibrium Equation for the $Al_2O_3 \rightarrow 2Al + 3O$ Reaction in Liquid Iron. H. Sawamura and T. Araki. (*Suiyokwai-Shi*, 1957, **13**, Dec., 331–334). More recent thermochemical data are used.

Measurements of Air and Gas Temperatures in Open Hearth Furnaces with Suction Pyrometers. M. Michalowski. (*Prace Inst. Hutn.*, (3), 147–151). A description is given of experiments with various designs of suction pyrometers to develop a type suitable for measuring air and gas temperatures in O.H. furnaces. The measurements obtained are claimed to be very accurate, and discrepancies from results obtained by other research workers are attributed to differences in heat exchange between thermocouples working in a medium of hot air or gases. It is concluded that suction pyrometers are the only means of obtaining true temperature readings in industrial furnaces, and that ordinary thermocouples are always subject to errors which it may or may not be possible to determine by experiment.

Calculations of the Amount of Combustion Gases and Induced Air in the Open Hearth Process. J. Szargut and J. Machniewicz. (*Hutnik*, 1957, **24**, Oct., 391–397). [In Polish]. Determination of the amount of combustion gases and the induced air is based on the mass balance of carbon, hydrogen, oxygen, and nitrogen. A numerical example of this method of calculation for an O.H. furnace of 370 t capacity is given.

Model Studies Aimed at Improvement of Checker Chambers. H. Hasimoto. (*Sumi. Met.*, 1958, **10**, Apr., 63–67). Work on model O.H. furnaces is described and checker design is improved. The effects of deflectors and double path chambers are shown.

The Optimum Conditions of Making and Casting of Steel Used for S-49 Rails. W. Hansel and B. Prusinski. (*Hutnik*, 1958, **25**, Jan.-Feb., 9–18). [In Polish]. Statistical investigations of: (1) time of quiescent boiling of steel in the O.H. furnace; (2) the effect of the contents of Mn and Si in the final product; (3) the effect of adding Al; (4) the temperature of molten steel just before pouring into a ladle; (5) time of cooling in the ladle before casting—are described. Recommendations are put forward.

A Rational Method for the Deoxidation of Ball-Bearing Steel in Acid Open Hearth Furnaces. V. A. Kudrin, E. I. Tyurin, and Yu. M. Nechkin. (*Stal'*, 1958, (7), 606–607).

Demag Strides Forward to Large Electric Furnaces. R. Genwo. (*Demag News*, 1957, (147), 1–12). An illustrated account of the evolution of the electric furnace from 1906 onwards is given. The growth of installations up to the present is shown and improvements are indicated.

Heat Transfer Investigations and Development of the Automatic Control of Power Input on the BISRA 10-cwt Arc Furnace. J. Ravenscroft and L. McGee. (*JISI*, 1959, **192**, May, 34–39). [This issue].

The Graphite Resistor Rod Furnace. T. A. Cosh and L. W. Sanders. (*BSCRAJ.*, reprint, 1957, Dec., pp. 9). Various details of construction and operation with an account of carbon, alloy and stainless steels made in such furnaces are given.

Decreasing the Hydrogen Content in Electric Steels. N. Chvorinov. (*Hutn. Listy*, 1958, **13**, (5), 402–406). By blowing oxygen into the electric arc furnace below the oxidizing slag prior to the reducing boil in duplexing a considerable decrease in the hydrogen content of the steel was attained, i.e. it reached about 1·5 ml/100 g. This increased slightly during the reduction boil. The increase showed a good correlation with the humidity of the atmosphere. The possibility of making electric steels with a hydrogen content guaranteed less than 2·0 ml/100 g should be within reach.

Refining Liquid Pig Iron in Electric-arc Furnaces. R. Durrer and G. Heintze. (*JISI*, 1959, **192**, May, 13–25). [This issue].

Casting of Steel. (*Centre d'Études Sidérur.*, 1958, 2 vols.). **Process of Ingot Solidification.** P. Vallet. (5–55). Heat conduction is formulated and Lightfoot's theory of semi-infinite ingots is developed. Practical cases of ingots of finite size are then discussed for rectangular, square and round or polygonal ingots, for insulated end or ends and for regular polyhedra or spheres. Initial solidification is then described and rate of solidification is formulated for various cases. Experimental work is then described in moulds and in sand and in highly conducting ingot moulds. In an appendix the general equation for conduction is developed in several forms and solved, and Lightfoot's cases and the sand mould case are formulated. (23 refs.). **Rimming and Semi-killed Steels.** J. Duflot. (5–49). The internal structure of the ingots is described and the effects of composition, casting process, thickness, and casting temperature and the incidence of segregation in rimming steels, and segregation and factors influencing it are considered. The properties of the steels are then given and the processes of manufacture are outlined. The theory of rimming and gas liberation is then gone into. (53 refs.). **The Heterogeneity of Ingots of Killed Steel.** A. Kohn. (5–52). Processes of solidification of pure metals and alloys are outlined and the mode of crystal growth is considered. Dendritic heterogeneity is discussed and in an appendix the calculation of concentration in interface zones is shown. Rate of cooling is then treated theoretically and experimentally and crystallization zones in killed steel are surveyed. Segregation patterns and processes and metal movements during solidification and their causes and the formation of banded structures in plain and alloy steels is described and illustrated. (74 refs.). **Apparatus and Processes in Casting.** M. Gombert. (7–40, Vol. II). Ladles and refractories, valves etc., factors in the life of ladle refractories and changes in steel in the ladle are reviewed. The casting process is then discussed from mould preparation, including tundish and other pouring methods. **Defects in Ingots.** H. Barret. (7–32). An illustrated account. **Design of Ingots.** H. Barret. (5–14). Size and shape, risers and hot tops are discussed. **Steelworks Ingot Moulds.** J. Durand and J. Duflot. (5–24). Conditions in moulds and consequences for design are discussed and details of construction are described and illustrated. Recommendations for design, production, and use are set out. **Preparation of Ingots and Semi-Finished Products.** J. Hautcolas. (6–62). Cooling of ingots is considered and possible defects are reviewed and methods for their detection, chemical and mechanical surface cleaning, and methods of eliminating defects are then considered. Descaling and milling are then described and cropping and the removal of defects. Control and organization is also outlined.

Thin-Walled Ingot Moulds for Killed Steel. A. M. Danilov. (*Metallurg*, 1958, (2), 19–20). Full-scale trials are described on 3·6 tonne ingots and nothing was found to choose between those cast in thick and those in thin moulds. As the latter were 1·1 tonnes lighter and as mould consumption was reduced by them from 2·23% to 1·7% of the weight of steel poured the thin moulds are to be preferred.

Investigation of Slab Moulds of More than Three Tons. J. Duflot and S. Dérot. (**Fonderie*, 1958, Oct., preprint). A detailed account is given of the design, internal and external, weight, production, cracking, and useful life of these moulds. (21 refs.).

Relationship between Ingot Mould Life and Bottom Plate Life and the Design. D. M. Slonim. (*Stal'*, 1958, (10), 894–899). Single row positioning of moulds on the bottom plate appears to produce transverse cracks and crazing if the wide faces are close together. The wide faces of the mould should be thickened. Possible small variations in shape and the effect of using cast bands round the moulds are discussed, also the question of giving the wide faces what is described as a spherical shape.—R. S.

Fast Scrap-Charging Boosts Open-Hearth Output. G. J. McManus (*Iron Age*, 1958, **181**, Mar. 20, 110–111). A new scrap-charging method in use at a works of the Armco Steel Corp. is described. Charging time has been reduced by an hour. Scrap is taken to the furnaces in special cars, and transferred to a hopper just outside the door of an O.H. Scrap feeds through the hopper into a charging-box which is used for charging in the usual way. Thus a train of charging-boxes is not necessary and considerable space and movement are saved.—D. L. C. P.

A Further Increase in Hearth Life in Open Hearth Furnaces. E. G. Druzhinan. (*Metallurg*, 1958, (4), 14–16). The use of basic refractories and improved thermal conditions to improve the life of the upper part of the furnace is described. Hearth life is only one-tenth of basic roof life. A study of stoppages for bottom repairs in different works was made.—R. S.

Three Ways to Handle Scrap. (*Steel*, 1958, **142**, June 9, 96–99). The new methods of charging scrap to O.H. furnaces described are: charging elevators, the Calderon Super Charger and the use of an endless chain and gravity to speed buggy movement.—A. G.

The Use of Natural-Gas Firing for Open-Hearth Furnaces in Austria. F. Huber and H. Mraz. (*Stahl Eisen*, 1958, **78**, May 15, 654–657). The change-over from oil firing to natural-gas firing is described. The calorific value of the home oil and the natural gas is equally expensive in Austria but substantial savings were made in the consumption of compressed air by using gas + 25% oil. The throughput of the furnaces was slightly lower when fired with gas.—T. G.

The Use of Photography for Studying Open Hearth Melting. E. S. Butyl'skii. (*Metallurg*, 1958, (5), 1). A note on cameras that can be used, without descriptions, and illustrations of slag at the end of melt down, at the boil on adding limestone and, a moment during the boil with a thin slag of basicity 1·8.—R. S.

The Efficacy of Blowing Compressed Air into the Bath of the Open Hearth Furnace in the Scrap Process. M. Ya Medzhibozhskii, V. P. Tunkov and L. A. Smirnova. (*Metallurg*, 1958, (4), 17–19). Work with compressed air in melt down and refining is described. Tap-to-tap time is shortened.—R. S.

Model Tests on the Flow in Open-Hearth Furnace Regenerators. M. Hansen. (**Stahl Eisen*, 1958, **78**, June 12, 804–812). Pressure distribution in checker work was studied for various cross-section ratios $F_1 : F_2$ (F_1 = cross-section of the inlet channel and F_2 = cross-section of free-flow area through the checkers). The significance of the $F_1 : F_2$ ratio is discussed in detail with particular reference to the drop of pressure in checker work.—T. G.

Operation of Open Hearth Furnaces with Waste Heat Boilers. D. E. Krasnozhen and G. I. Moiseevich. (*Metallurg*, 1958 (6), 17–20). The first waste heat boilers in the Soviet Union installed in the block system (i.e. with all boilers operating on a single drum separator and having a common steam superheater) and their special circulation pumps are described. Factors affecting furnace productivity when using such boilers are reviewed. Experience at Kuznetsk showed that it was preferable not to use the block system.—R. S.

Developments in Metallic Recuperators. T. E. Dixon and H. A. Kuhne. (*Iron Steel Eng.*, 1958, **35**, Jan., 127–134). Details are given of several European installations of flue, tubular and radiation type recuperators, direct-fired gas preheaters, and combinations of these.—K. E. J.

Analyse for Combustibles, Too. (*Steel*, 1958, **142**, May 26, 108–111). On the conversion of 5 O.H. furnaces from oil to oil-natural gas firing, flue-gas analysers have been used as a means of control. Advantages of such instrumentation are listed.—A. G.

Mains Frequency Melting: A New Furnace for Alloy Steel Production. (*Iron Steel*, 1958, **31**, Mar., 111). The world's first mains-frequency coreless induction furnace for the regular production of high speed steels has recently been installed by Birlec at the works of Inca Steel Co. Ltd. It is 1½ t capacity, has a power input of 450 kW, and an output of about ½ t/h.—G. F.

On the Shortening of the Reducing Period in Electric Furnace Smelting. Fang Bing, Sueng I-kwang, Hoo Chwang-chi, Ho Chein-chu, Liu Cheng-chi, Wang Ching-tang and Hsing Chung-shu. (*Acta Met. Sin.*, 1956, **1**, (4), 311–324). [In Chinese]. For some steels of various carbon contents, reducing periods were shortened by 20 min. For some low-carbon heats, Fe Si was increased by 20% and added in advance. The shortened period leads to efficient desulphurization and deoxidation, improved mechanical properties and a 7% increase in production rate. It is suggested that reducing times and deoxidation practice should vary with the carbon content of the steel. (12 references).—K. E. J.

Survey of Arc Furnace Installations on Power Systems and Resulting Lamp Flicker. A.I.E.E. Sub-committee. (*Trans A.I.E.E.*, 1957, **76**, Part 2, 170–183). With discussion.

Development in the Field of Arc Furnaces. K. Schulz. (*Elektrowärme*, 1958, **16**, July, 241–247). Steel furnaces are considered. They give rise to voltage drops when run from the mains on account of the variable current input. Trials in the U.S. with drilled electrodes are noted. A working factor is developed based on the relation of the energy actually converted in the arc to the possible maximum.

The Principles of the Economical Use of Electric Current in Arc Furnaces. V. Keclik. (*Hutnik* (*Prague*), 1958, **8**, Apr., 127–130). For every arc furnace, the working characteristics for the most common level of secondary voltage should be calculated, and on the basis of these characteristics the most advantageous loading in amperes can be calculated for each voltage level. The method of calculation is elaborated and the most advantageous way of economizing in the use of current and its maximum utilization in arc furnaces is indicated, with the resultant production economy.

Experience in Switzerland with Mains Operation of Arc Furnaces. U. V. Büttikofer. (*Elektrowärme*, 1958,**1 6**, July, 247–252). Flicker in the distribution system from the power supply has been produced. The recent enlargement of the furnace units has made this worse. Steps taken with small, medium and large furnaces are described.

Arc-Furnace Corrective Equipment, Using a High Value of Buffer Reactance. H. W. Harper, T. R. Macon and A. F. Sedgwick. (*Trans. A.I.E.E.*, 1957, **76**, Part 2, 74–80).

Selection of Buffer Reactors and Synchronous Condensers on Power Systems Supplying Arc-Furnace Loads. C. Concordia, L. G. Levoy and C. H. Thomas. (*Trans. A.I.E.E.*, 1957, **76**, Part 2, 123–135).

Electrographite. Its Production and Use. F. Sinkel. (*Elektrowärme*, 1958, **16**, Feb., 43–49). The production of electrodes by blending, pressing and firing is described and its uses for steel furnace electrodes and for non-metallurgical uses are surveyed.

Bath Reactions of Electric-Furnace Steelmaking with Oxygen Injection. Fang Bing, Wang Ching-tang, Hoo Chwang-Chi, Liu Cheng-chi and Hsing Chung-shu. (*Acta Met. Sin.*, 1956, **1**, (3), 243–254). [In Chinese]. During oxidizing, under favourable conditions, carbon is removed at a rate of 0·015–0·020% per min.; (FeO) and [O] decrease significantly and approach to equilibrium with [C]. Dephosphorization is not very effective, the average removed being 0·004%, although with dephosphorization during melting, [P] can be reduced to < 0·015% at the end of the oxidizing period.—K. E. J.

The Uses of Oxygen in the Production of Plain Carbon and Low-Alloy Steels in the Basic Arc Furnace. R. Peters. (*Neue Hütte*, 1958, **3**, July, 409–415). After complete melting-down and addition of the fluxes the current of the 20-t capacity arc furnace was switched off and the steel refined with oxygen blown at a pressure of 10–12 atm. into the melt. Substantial saving in time as compared with ore refining were obtained. The P content of the steel could be kept at the 0·020% level, but no appreciable reduction in nitrogen was observed. A Mn content of 0·20% was attained without any addition ferro-manganese.—T. G.

Can Ultrasonics Improve Steel Ingot Quality? P. M. Unterweiser. (*Iron Age*, 1958, **182**, Sept. 11, 178–180). Russian workers claim that the ultrasonic treatment of steel ingots improves soundness and decreases gas solubility. American reaction is cautious in view of the difficulties of treating large ingots in this way.—A. G.

Austenitic Manganese Steel. H. Thomas. (*Castings*, 1958, **4**, Sept., 13, 15, 17, 19, 21, 23). Casting methods are described, melting, pouring, moulds and cores, heat-treatment, cleaning, control and metallography are summarized. An appendix on Mn determination is added, two volumetric methods being given.

No. I Forging-quality Steels. W. Ash. (*Met. Treatment*, 1958, **25**, Sept., 385–386). A synopsis of the first lecture of this year's N.A.D.F.S. Spring series. Production, casting, segregation in the ingot and surface treatment are outlined. Discussion is also reported.

Continuous Casting of Steel in Great Britain. (*Machinery Lloyd*, 1958, **30**, Oct. 25, 76–79). [In English and Spanish]. A general illustrated account of the Barrow, Low Moor and BISRA processes.

Continuous Casting of Steel. V. I. Yavoisky and V. B. Joshi. (*Indian & Eastern Engineer*, 1958, **123**, Aug., 109–115). Brief descriptions of the machines at "Stalino" and "First of May" plants and of the bottom casting machine are given, with diagrams and cost data. (6 refs.).

Observations Regarding Properties and Performance of Continuously Cast Low-Carbon Steel Products. M. Tenenbaum, R. N. Edmondson and L. Mair. (*Trans. Met. AIME*, 1958, **212**, Aug., 431–445). The properties of products made from rimming and killed low-carbon steels were examined. The final product from Al-killed steels was seamy and slivered due to inclusions, but Si-killed steels gave relatively good surface conditions. All steels had higher tensile values and were harder and less ductile than those made by the conventional O.H. process. Results of processing are discussed.

Progression of the Freezing Front and the Temperature Distribution in Ingots during Solidification. J. W. Hlinka and V. Paschkis. (*A.S.M. preprint* 97, 1958, pp. 21). Generalized charts are given. The range of variables include metals commonly used in industry in superheated and non-superheated and preheated and sub-cooled moulds.—E. E. W.

Piping and Segregation. G. R. Bashforth. (*Brit. Steel.*, 1958, **24**, Sept., 288–293). A discussion of the causes of piping and segregation in steel ingots and of the value of hot tops. The various factors producing defects in casting pit practice are considered.

FOUNDRY PRACTICE

Foundry Techniques. H. Haynes. (*Brit. Foundryman*, 1958, **51**, July, 347–352). A lecture, dealing with the construction of a sand mixer, a method of quick pattern change, the knock-out of core barrels, and the use of gas in the foundry, etc.—T. G.

Ferrous Castings. T. E. Eagan. (*Met. Prog.*, 1958, **74**, Oct., 118–119). Part of a review of everyday uses for metals. Grey, nodular, malleable types and steel are briefly considered, with an account of current specifications of the ASTM.

Cast Iron. ASTM Committee A-3. (*ASTM preprint*, 1958, (2) pp. 4). Revision of the automotive grey iron castings for brake drums and clutch plates specification is given.

Design of Cast Components. H. G. Goyns. (*Eng. Foundryman*, 1958, **23**, July, 54–66). A general discussion of ferrous and non-ferrous metals and the fundamental principles of design of castings are given.

Radio Isotopes and their Use in the Foundry Industry. F. C. Pollard. (*Castings*, 1958, **4**, July, 39–43). A brief review.

Aspects of Russian Engineering Industry. (*Machinery*, 1958, **93**, Aug. 27, 456–469). The Central Research Institute of Technology and Machine Building is described. Work

mentioned includes a new shell-mould making technique, the Mg process for spheroidal graphite cast-iron for the investigation of which apparatus has been constructed, and the work of corrosion, metal cutting, and strength of materials departments is also indicated. A peening machine is also described.

On the Occurrence of Oxygen in Cast Iron. G. Östberg. (*Trans. Met. A.I.M.E.*, 1958, **212**, Oct., 678–685). Oxygen solubility in cast iron was derived from existing data on equilibria between O, C, and Si in molten Fe alloys, and the results obtained by analyses compared with the derived values. Analysis of a malleable cast iron spoon sample by vacuum fusion followed the theoretical trends in most cases.

Constitution, Production and Mechanical Properties of Ni-Resist. R. Barton. (*B.C.I.R.A.J.*, 1958, **7**, Aug., 299–315). Cupola practice, foundry technique, machining speeds and corrosion properties are dealt with and a list of applications is added. Mechanical properties are also given.

Catton's Increase Productivity by Improved Mechanical Handling. (*Foundry Trade J.*, 1958, **105**, Sept. 25, 387–388). The transport of liquid steel from furnace to moulding shop is outlined.

What is Preventive Maintenance? (*Mod. Castings*, 1958, **34**, Sept., 20–23). Extracts from discussions on preventive maintenance from talks at the 9th Plant Maintenance and Engineering Show at Chicago.

Saving Through Preventive Maintenance. L. Wittmayer. (*Mod. Castings*, 1958, **34**, Sept., 29). Records enable the known average life of wearing parts to be calculated by the Maintenance Department of the Electric Steel Foundry Co., Portland, Ore., and breakdown times can be reduced by replacing parts before they fail.

Your Foundry and Preventive Maintenance. C. E. Fausel. (*Mod. Castings*, 1958, **34**, Sept., 48–53). A preventive maintenance section was instituted at the Danville foundries of General Motors, to reduce standstill periods due to maintenance work. A description of the system and its working is given.

Recent Additions at North British Steel Foundry. (*Found. Trade J.*, 1958, **105**, Oct. 23, 515–517). Notes on the Bathgate works, showing improvements since the last article published in 1951, are given.

Further Developments at the Derby Foundry of International Combustion Ltd. (*Foundry Trade J.*, 1958, **105**, Aug. 28, 253–256). A report on the operation of a mains-frequency furnace whose installation was described previously, and the cleaning of castings by the "Hydroblast" system, using a water jet, are the topics included.

Brockmore Foundry Developments. (*Found. Trade J.*, 1958, **105**, Oct. 9, 443–448). An account of the foundry at Brierley Hill, Staffs., where hot-blast cupolas have been installed and shell moulding has been introduced. A visit to the works is described.

Link-Belt's New Foundry Provides Efficient Operations. R. H. Herrmann. (*Foundry*, 1958, **78**, Aug., 40–47). Standard and pearlitic castings weighing from 0·02 to 70 lb are produced in green sand and shell moulds at a rate of 1 250 t monthly in this mechanized foundry. It includes materials handling equipment and two shell-moulding systems. Layout and operation of the foundry including hot-blast cupolas, moulding techniques, annealing, cleaning and dust control are described.—T. G.

Survey of Belgian Foundries. I. Compagnie Generale des Conduites d'Eau. (*Found. Trade J.*, 1958, **105**, Sept. 4, 281–285). **II. Fabrique Nationale D'Armes de Guerre, S. A. Herstal.** (287–290). **III. S. A. Cockerill-Ougrée.** (Sept. 11, 317–321). An illustrated survey.

The New Zealand Foundry Industry. W. F. Chubb. (*Castings*, 1958, **4**, July, 7, 9, 11, 13, 15, 17, 19, 21–23, 25–29). Local sands are described and sand control, moulding methods, melting and other topics are reviewed.

Its Time to Reappraise Foundry Automation. J. F. Miller. (*Iron Age*, 1958, **181**, May 8, 97–99). The benefits and limitations of automation in the foundry are considered. The value of high-speed moulding machines depends on their integration into the process. Other fields for improvement of automatic moulding equipment are now more important than speed, e.g. cost of operation, dependability, quality of output, worker morale and efficiency.—D. L. C. F.

Possibilities of Attaining the Highest Degree of Mechanisation and Automation in the Foundry. H. Bergmann and K. Kaiser. (*Giesserei*, 1958, **45**, June 19, 365–376). After pointing out the need for mechanising transport in the moulding shop, and discussing ways in which this can be carried out, the automation of various foundry processes is dealt with.

Automated Moulding and Pouring: Designed for Production-Jobbing Foundry. (*Foundry*, 1958, **86**, June, 70–76). The new automated foundry of George Fischer Ltd., Schaffhausen, Switzerland, is described. For the direct operation, one man-hour is required per t of castings, with an average casting weight per mould of 60 lb. All programme cycling devices operate on the mechanical-pneumatic principle, without electronic controls. The superimposed electrical system enhances the safety of the operation and indicates any malfunction of the installation. The individual operations are described.—T. G.

Grey Iron Foundry Pursues Continued Plant Improvement. K. L. Mountain. (*Foundry*, 1958, **86**, July, 98–101). The reduction of the melting capacity of the cupolas with a change to a continuous-tapping basis and a conversion to water-cooling brought about manufacturing economies, cut the man-hours by half and increased output. Foundry practice is briefly described.—T. G.

Shotton Bros., Developments. (*Foundry Trade J.*, 1958, **105**, July 17, 67–72). An illustrated account of the Halesowen works.

"Gateway to the Future": Samuel Osborn's Facilities for Precision Casting. (*Foundry Trade J.*, 1958, **105**, July 10, 33–52; July 17, 77–79). The production of a number of items is described and illustrated.

A Water Cooled Cupola Installation. A. P. Alexander and W. J. C. Ritchie. (*Engineer Foundryman*, 1957, **21**, Apr., 37–39: discussion, 39–42).

Automatic Charging Equipment for Cupolas Operated by One Man. W. Dannemann. (*Giesserei*, 1958, **45**, June 19, 378–380). A description is given of an automatic charging device for cupolas operated by one man. It is claimed to be safe and efficient, and has been given a full-scale trial for eight months.

The Controlled-Slag Hot-Blast Cupola. D. Fleming. (*Brit. Found.*, 1958, **51**, June, 291–302). The design factors arising out of experiences gained in operating two controlled slag hot-blast cupolas are discussed with particular reference to the melting zone of the cupola. The importance of controlled high melting temperatures and the air velocity at the tuyeres is stressed. The evolution of a conical shell design is explained and a theory is advanced to account for the behaviour encountered with a 'fully cooled' melting zone. The advantages of the controlled-slag hot blast cupola are briefly summarized and the desirability of increasing the blast temperature for future plants is considered.—B. C. W.

The Injection of Additional Charges and of Alloying Additions into the Cupola. A. Rexroth. (*Giesserei*, 1958, **45**, July 17, 417–420). Altering the composition of the melt in the cupola by additions charged from the top is usually difficult, particularly if productivity has to be kept up. The author describes a device for injecting swarf or alloying additions directly into the melting zone by the use of compressed air or gas. A magnetically operated valve allows the time of the 'shots' to be predetermined. The device and its optimum location are described in detail. The additions successfully injected are listed.

A Contribution to the Theory of Carburization in the Cupola. R. Krzeszewski. (*Giesserei Techn. Wiss.*, 1958, **21**, July, 1089–1096). The solution of carbon in Fe–Si alloys is controlled by the diffusion rate of carbon and follows the general Nernst theory of solubility. The author discusses the theory of carburization in the cupola and derives an equation: $C_2 = \overline{C}_\infty - K(\overline{C}_\infty - \overline{C}_1)$, where C_2 is the carbon content of the cupola iron, $\overline{C}_1$ the carbon content of the iron of the charge, $\overline{C}_\infty$ the theoretically highest carbon content obtainable and K a constant depending on the diffusion coefficient and the carburizing time.—T. G.

Silicon Fluctuations of Cupola-Processed Cast Iron. J. Drachmann. (*Giesserei Techn. Wiss.*, 1958, **21**, July, 1097–1106). The author presents a mathematical-statistical solution for Si fluctuations occurring in cast iron from the cupola. The method is extended from a uniform charge to charges made up of a number of components of various compositions. The author concludes with some recommendations to foundries on how to reduce fluctuations in the Si content.—T. G.

The Purification of Cast Iron by Oxidation. R. H. T. Dixon. (*Brit. Found.*, 1958, **51**, Apr., 197–203). Experiments designed to study the removal of impurities from molten cast iron by oxidation are described. The methods used were oxygen blowing on to the surface of the melt, oxygen bubbling through the metal, and oxidation with suitable slags. Si, Mn, Ti, Pb, Cr, Ni, Cu, and Al could be oxidized by all treatments, and P and S removed by the combination of oxidation and a basic slag. Bubbling the gas through the molten metal was the most effective technique, but blowing oxygen on to the surface of the melts was the simplest. Treatments with slag might be the most economic, but it would have to be done in a heated vessel with a lining resistant to slag attack.—B. C. W.

Contribution to Deoxidation and Desulphurization in the Cupola. K. Bandow and K. Wagner. (*Giesserei*, 1858, **45**, July 17, 409–417). The authors stress the complexity of the problems involved in deoxidation and desulphurization in the cupola and recommend a number of methods for both purposes.—T. G.

Heat-exchangers. E. Longden. (*Brit. Found.*, 1958, **51**, Apr., 193–197). Two new designs for heat-exchangers intended for use with hot-blast cupolas, melting furnaces, or heat-treatment furnaces are described.

Making Soft Iron Castings. (*Foundry Trade J.*, 1958, **105**, July 10, 53; from *Bull. Centre Technique des Ind. de la Fonderie*). Cupola charges tried to produce plates with a hardness below 145 Brinell are discussed. A 100% haematite pig-iron charge was finally evolved to give high C and low P with 2·5% Si and a hardness as low as 110 Brinell.

The New Electric Melting Shop at Brymbo Steel Works. W. H. Diamond and S. J. Hinder. (*Weld. Met. Fab.*, 1958, **26**, Apr., 120–125). As an example of the many advantages to be gained by welding applied to structural steelwork, the authors describe the design and construction of the new electric melting shop at Brymbo Steel Works Ltd. This is an all-welded structure with tubular frames and continuous gantries.—G. F.

Electric Melting Furnace Applications. L. G. N. Edwards. (*Iron and Steel Review*, 1957, **1**, Nov., 31–35). The advantages of each type of electric furnace are indicated, together with details of capacity, rating, application and main features.—A. G.

Electric Induction Furnaces in the Foundry. J. Muissieux. (*Usine Nouv.*, 1958, Spring, 135–140). Induction furnaces are classified according to constructional features rather than frequency. Various types and their application in the foundry are discussed.—A. G.

Classification of the Types of Cast Iron Resistant to Different Temperatures. (*Fonderie*, 1958, Mar., 136–142). The most suitable types of cast iron to withstand various service conditions are tabulated and a number of practical suggestions are made for controlling the chemical composition of pearlitic cast irons in order to improve their resistance to graphitization.—B. C. W.

The Material Balance in Cold-Blast Cupolas. H. Pacyna. (*Giess. Tech. Wiss.*, 1957, Oct., 955–966). Jungbluth's equation for materials balance in a cupola is given, described and extended. The calculation of combustion ratios and the theoretical waste gas analyses are described. The influences on the combustion ratio of coke additions, the size of the coke lumps, the amount of blast and other factors are discussed. A calculation is given for the amount of blast required per kg of carbon, with reference to the losses. The article is well illustrated with graphs.—R. J. W.

Development Tendencies of Cupola Melting Practice in the Soviet Union. L. M. Marienbach. (*Giessereitechn.*, 1958, **4**, July, 159–161). Modern lines of development in Soviet cupola practice are outlined. These include a tendency to higher tapping temperatures (1500–1550° C is aimed at for the immediate future), the use of special fuels, new equipment and design, and the use of oxygen-enriched blast. (26 refs.).

The Importance of Certain Factors for Smooth Cupola Operation. (*Fonderia*, 1958 **7**, May, 221–224). [In Italian]. The influence of such factors as furnace lining, coke consumption, and quality, furnace height and lines and fluxes are discussed.—M. D. J. B.

An Easy Method of Measuring the Supply of Air to the Cupola. A. Mal. (*Fonderie Belge*, 1958, June, 187–189). A method is described of measuring the supply of air to a cupola by the use of a diaphragm and differential manometer.

Systematic Experiments and Practical Experiences with HC-Coke. R. Ziegler. (*Giesserei*, 1957, **44**, Dec. 5, 729–739). The nature of high-carbon-coke is discussed in terms of its physical–chemical properties and its microscopic texture; it is compared with other foundry cokes. Investigations using an experimental cupola at the Austrian Foundry Institute are described. Values for the melting performance, iron temperature, blast volume required, combustion ratio, melting gains and losses, mechanical properties, wear of the cupola lining and calorific balance are given and discussed at length. The changeover from foundry coke to HC-coke is described and followed by practical experiences using the latter.—R. J. W.

Comparison between the Use of HC-Coke and Normal Foundry Coke in the Cupola. A. Dahlmann. (*Giesserei*, 1957, **44**, Dec. 5, 740–743). The initial conditions necessary for an enquiry form to be satisfactorily evaluated are enumerated. The effect of different grades of coke on the temperature of the iron is discussed. The characteristics and advantages of HC-coke and the prerequisites for its successful use are described. The melting losses of the accompanying elements and the consumption figures for the patching material are given.—R. J. W.

Efficient Use of Metal Chips. I. N. Goncharov, I. A. Azarov, and Yu. G. Dorofeev. (*Vestnik Mashin.*, 1958, (6), 46–49). Briquettes of steel, cast iron and non-ferrous metal chips can be used in foundries as a charge for the casting of various machine parts. The process is explained and examples cited of a number of parts made of steel chips. This sets free rolling capacity for other essential work.—L. H.

The Use of Calcium Chloride in the Cupola. H. Timmerbeil. (*Giesserei*, 1958, **45**, Aug. 28, 513–516). In Using CaC_2 in acid cold-blast cupolas it has been found advantageous to make use of a special carbide with a relatively low melting point (about 1650° C). The addition of 1·75–2% CaC_2 has the advantages of economizing coke additions, with a consequent reduction in the iron sulphur content, and increased output.

Improved Gas-Heated Industrial Furnace. F. Brunn. (*Giessereitechn.*, 1958, **4**, April, 80–83). In the novel furnace described and illustrated the waste gases pass from the floor through the face wall of the furnace into the flue, so that the whole flue system under the furnace has been eliminated.—L. J. L.

Sulphur in Iron Alloys, and How to Remove It. (*Tecn. Indust.*, 1958, **36**, Mar., 217–218). [In Spanish]. The effect of sulphur in cast irons and the influence of various alloy elements upon its behaviour are described. The remedies given are (*a*) neutralization by adding Mn as spiegeleisen in the cupola, and (*b*) desulphurization by the sodium carbonate or calcium carbide processes.—P. S.

Experiments to Improve the Mechanical Properties and the Machinability of Cast Iron by Mg Treatment Followed by Tempering. B. Beyer and H. Seliger. (*Giessereitechn.*, 1958, **4**, July, 153–158). Experiments were carried out to investigate the influence of Mg additions on the mechanical properties of three chill-cast irons with different P contents. The influence of cooling conditions after the graphitization anneal on plastic properties was investigated. As was to be expected, machinability was best with a ferritic structure.

Silicon-Containing Ferritic Cast Irons. M. Pujol Roig. (*Inst. Hierro Acero*, 1958, **11**, Apr.-June, 105–117). [In Spanish]. The heat-resisting cast irons are reviewed briefly and an account of an experimental study of the influence of silicon, in amounts ranging from 4 to 8·5%, upon mechanical properties, microstructures and oxidation resistance is given. The best combination of strength and heat-resistance, compatible with homogeneity in various section thicknesses and ferrite stability at high temperatures, was found to be the 6·5% silicon iron (for use up to 950° C). An iron with 5·5% Si has better mechanical strength and is useful up to 850° C. Further improvement in strength may be obtained by making the graphite spheroidal.—P. S.

The Question of the Formation of Spheroidal Graphite in Cast Iron. K. Grütter. (*Promotionsarbeit, Eidgenössischen Technischen Hochschule, Zürich*, 1957, No. 2467, pp. 63). A method of determining the surface tension of liquid metals is described, with the help of which the surface tension of various molten pig and cast irons was measured. A close relationship between surface tension and sulphur content was found; on the other hand no temperature relationship was established. It was concluded from the results that the occurrence of a given type of graphite was associated with a definite surface tension, spheroidal graphite being formed at a tension of 1300–1400 dynes/cm. Other physical properties were discussed. (54 refs.).

Quality Grey Cast Iron Used in Naval Castings. R. F. Poirot. (*Fonderia*, 1958, **7**, June, 258–259). [In Italian]. A brief review is given of the compositions and properties of spheroidal graphite cast iron and of sorbitic, bainitic, and martensitic irons. Pearlitic iron with small additions of Ni (1·5%) and Cr (0·5%) is considered preferable for large naval castings which often have complex shapes.—M. D. J. B.

The Bührer Plant for the Production of Malleable Iron Castings at the George Fischer Works-Schaffhausen. W. Götz. (*Fonderia Ital.*, 1958, **7**, Sept., 315–330). [In Italian]. The article gives a detailed review of the "Bührer" process developed at the George Fischer works for the production of quality malleable iron castings.—M. D. J. B.

Production of Very Large Castings from 13% Chrome Steel. G. Schmidt. (*Giesserei*, 1958, **45**, Jan. 16, 43–47). The development of the production of steel castings from small and medium weights to very heavy castings with a cast weight of about 120 t is described. The construction of the moulding pits from concrete is a major operation. Some of the difficulties encountered during the casting operation are described and the remedial measures taken. The manufacture of the large moulds and cores is described and the cooling of the mould after casting discussed. The mechanical properties of the casting are estimated from test pieces taken from cast-on ledges.—R. J. W.

Properties of Some Foundry Sands Found in the Auckland Area. E. D. Burt and P. A. Neyland. (*N.Z. Eng.*, 1958, **13**, June 15, 217–218).

Sand Concentration by Vibration. W. Gesell. (*Giesserei*, 1958, **45**, May, 295–300). The literature on the subject is surveyed. Results are reported of attempts to apply laboratory data to industrial practice. Theoretical results are developed to embrace the operating methods of all industrial machines for this purpose.—L. J. L.

Studies on Graphitisation of White Cast Iron. I. The Effect of Carbon. K. Futakawa and K. Okabayashi. (*Nippon Kinzoku*, 1957, **21**, Apr., 256–259). [In Japanese]. Graphitization times are determined for the first stage and the direct and indirect transformations of the second stage of graphitization, for irons containing 1·3% Si and 2·15–2·69% C.—K. E. J.

Study on Graphitic Steel. IV. Effect of Carbon Content on Graphitic Cast Steel. T. Sato and S. Toya. (*Nippon Kinzoku*, 1957, **21**, Apr., 234–238). [In Japanese]. Results are given for steels containing 1·0–1·8% C and 1·5% Si. The time for graphitization at 800–1000° C is decreased by forging cast specimens. Cast steels containing > 1·4% C easily graphitize by annealing at 950° C for 3 h and cooling at 50° C/h, giving spheroidal graphite. The best tensile and elongation properties are shown by steels containing 1·4–1·6% C.—K. E. J.

Research on the Inoculation of Molten Iron. II. On the Behaviour of Inoculants in Mg-Treated Molten Iron. M. Okamoto and R. Yoda. (*Nippon Kinzoku*, 1957, **21**, Feb., 103–106). [In Japanese]. Results are given from microstructure studies of the effects of inoculants in Mg-treated iron, and of inoculants together with Mg alloy placed in contact with molten iron. The reactions are more effective with lip-pouring than with bottom-pouring. Si is more effective as an inoculant if placed in contact together with Mg alloy than if used as Si–Mg alloy. **III. On the Principal Factors Governing the Inoculating Effect with Spherulitic Graphite Iron.** (Apr., 249–252). Inoculants such as CaSi are inadequate in strongly deoxidized iron. The inoculating effect is best with moderate size of inoculant and thorough distribution. The rate of spherulitic graphitization is lower when Si is used after Mg treatment than before. Good results are obtained with Mg treatment at high temp. followed by Si inoculation at low temp.—K. E. J.

Critical Consideration of the Formation of Spheroidal Graphite in Cast Iron. E. Scheil and A. Wittmoser. (*Z. Metallkunde*, 1958, **49**, May, 256–267). Three hypotheses of the formation of spheroidal graphite are reviewed and compared. It is concluded that further work is required to establish the facts.—L. D. H.

A Research on the Workability of Cast Iron with Spheroidal Graphite. Chang Tso-mei, Shu U-yung, Gau Tze-ming and Kuoh Sheng-chuen. (*Acta Met. Sin.*, 1956, **I**, (2), 165–188). [In Chinese]. The best hot-working temperature is in the range 700–1100° C, varying with the type of stress applied and speed of working. Maximum amounts of working are quoted for tensile, compressive and rolling stresses. Results nearest to practical results are given by upsetting and small-scale rolling tests. The material has a higher stress and workability under compressive than tensile stress, and has a brittle temperature range between 200° and 650° C. (12 references).

An Economic Method for Treating Liquid Cast Iron With Ferro-Alloys Containing Magnesium in Order to Obtain a Spheroidal Graphite Cast Iron. N. Volianik. (*Fonderie*, 1958, Mar., 119–135; *Fonderie Belge*, 1958, **28**, May, 165–168). Previous work on the addition of Mg to cast iron is reviewed and the existing processes are outlined. Experiments carried out to investigate the possibilities of treating irons with a ferrosilicon–Mg alloy are then described and the results summarized. By introducing the granulated alloy below the surface of the metal it was possible to produce spheroidal graphite in irons containing 0·1–0·15% S without the necessity for a previous desulphurisation.—B. C. W.

Malleable Iron Foundry. (*Engineer*, 1958, **206**, July 25, 142–143). An account of a visit to Shotton Bros., Halesowen, Birmingham.

Black Heart and White Heart Malleable Cast Irons. P. Gailly. (*Usine Nouvelle*, 1958, **14**, Mar. 20, 33, 35). A general review of properties, tolerances, reinforcement and uses.

Ductile Iron in the Machine Tool Industry. R. M. Bronson. (*INCO Mag.*, 1958, **27**, Apr., 11–15). Compositions and mechanical properties are given, machinability, wear resistance and pressure-tightness are discussed and typical parts are shown.

Pearlitic Malleable Iron—An Industry Report. J. H. Lansing. (*Met. Prog.*, 1958, **73**, May, 102–103). Properties and applications are described.

Castings Limited, Expand Their Facilities for Malleable Production. H. G. Hall. (*Foundry Trade J.*, 1958, **105**, July 24, 97–107; July 31, 131–138). An illustrated account of the new foundry at Brownhills, Staffs. Equipment and operations are reviewed.

Problems in Making Stainless Steel Castings. E. A. Schoefer. (*Foundry*, 1958, **86**, Apr., 114–119). Some of the problems involved in producing Fe–Cr and Fe–Cr–Ni castings for heat, corrosion, or abrasion resistance, are discussed. The manufacturing problems are those arising in melting, moulding and core-making, cleaning, heat-treatment, and inspection and control.—B. C. W.

Castings for Tougher Jobs. C. F. Joseph. (*Met. Prog.*, 1958, **73**, May, 104–108). The author describes the production, heat-treatment and properties of ArmaSteel, a pearlitic malleable iron containing 0·001–0·004% B to counteract Cr and small amounts of Bi to prevent the formation of primary graphite.

Stainless Castings with Unusual Hot Strength. C. Tylka. (*Mat. Design Eng.*, 1958, **47**, Mar., 104–105). By close control of casting design to reduce centre-line porosity, Cooper Alloy Corp. produces cast stainless steel valves and fittings with strengths 20% higher than required by the specification for unfired pressure vessels. Brief details are given of casting production and properties.

The Phenomenon of the Aging of Core Sands Containing Dextrin. A Method of Analysis for Dextrins in the Foundry. C. Konlein. (*Fonderie*, 1958, Mar., 113–118). A method for following the hydrolysis of dextrin by optical measurements and solubility determinations is described. The correlation between the extent to which dextrins age and their behaviour as core binders is discussed.—B. C. W.

Controlling Variables in Processing Shell Moulding Sands. J. E. Bolt. (*Foundry*, 1958, **86**, Apr., 107–109). The results of tests on the effects of certain variables on the tensile strength and cycle time of resin-coated sand for shell moulding, are summarized. The variables considered included resin/solvent ratio, resin content, type of solvent, water content of sand, sand temperature and addition sequence.—B. C. W.

The Importance of Clay Particle-Size. W. E. Gruver jun. (*Foundry*, 1958, **86**, July, 94–96). The three methods used in the foundry for the determination of the fine particle size of soils and sand are reviewed. All are based on Stoke's law: the pipette method, A.F.S. clay method and hydrometer method. The methods are discussed and the advantages of the hydrometer method stressed.—T. G.

An Introduction to Patternmaking in Plastics. H. G. C. King. (*Brit. Found.*, 1958, **51**, June, 282–290). The materials and equipment required for the manufacture of epoxy resin plastic patterns are listed and the preparation of master patterns and the production of moulds is described. The manufacture of plastic patterns by solid casting, by shell casting with a preformed core, and with fibreglass fabric, is considered.—B. C. W.

Pouring Times of Sand Castings. J. S. Abcouwer. (*Giesserei Techn. Wiss.* 1958, **21**, July, 1107–1113). The author discusses running and gating systems and derives a simple equation for heat transfer between metal and mould in which two factors are dominant: superheating of the melt and heat loss during pouring. Ferrous and non-ferrous metals are considered.—T. G.

Risering of Steel Castings with Exothermic Sleeves. H. F. Bishop, H. F. Taylor and R. G. Powell. (*Foundry*, 1958, **86**, June, 54–59). Refractory materials are described which can be formed into sleeves and incorporated into moulds to form the riser cavities. In contact with molten steel they react exothermically and develop temperatures of about 2950° F. These materials are based on the metal oxide–aluminium basis. The most efficient use of the materials in risering practice was studied under the headings: The extent to which riser diameters can be reduced when these materials are employed; the extent to which riser volumes can be reduced; and the effect of these materials on feeding range.

The Influence of Beneficiation on the Green Properties of Synthetic Moulding Sand. W. Patterson and D. Boenisch. (*Giess. Tech. Wiss.*, 1958, Jan., 995–1006). The dependence of the properties of moulding sand on the grinding time, the dispersion of the binding clay, the orientation of the clay particles and the roughness of the sand grains is described. The effect of final water content, of additions, of speed of drying, and of the degree of mechanical grinding have all been investigated. The effect of a double dressing technique is finally described.—R. J. W.

The Working of Foundry Earths and Sands. G. Somigli. (*Fonderia Ital.*, 1958, **7**, Aug., 284–296). [In Italian]. Comprehensive data are given on methods of preparing compounds and sands for use in foundries. Information is given on the most modern plant and equipment available and on how this can be used in mechanized foundries.—M. D. J. B.

On Glauconite-Bearing Sand. H. Jungbluth. (*Giess. Tech. Wiss.*, 1957, Oct., 967–974). The literature on glauconite is first reviewed (14 references). The methods of investigation used are described. A correlation is established between the grinding time and the effective binding properties of glauconite. The grinding time has to be 5–10 times longer than normal to obtain the optimum properties. A large amount of data is presented in tabular and graphical form. Glauconite bonded sand is contrasted with clay-bonded.—R. J. W.

Behaviour of Green Moulding Sands during Shock Heating as Regards the Occurrence of Surface Defects on Castings. H. G. Levelink. (*Giesserei*, 1958, **45**, Jan. 2, 1–9). The methods of carrying out the experiments are first described. Particular attention is given to the behaviour of the surface layer during shock heating. Other factors considered include the thermal conductivity and heat capacity of the sand. The results are discussed and the importance of the investigation for evaluating the behaviour of moulds is stressed.—R. J. W.

On the Theory of Chemically Hardened Moulding Sands. L. Petržela. (*Slévárenství*, 1958, **6**, (5), 129–137). Developments in the theory and application of the CO_2-process in Czechoslovakia since 1947 are surveyed, and the technologically most important results obtained are summarized.—P. F.

The Use of Plywood Made from Wood Shavings in Pattern Building. F. Härtling. (*Giesserei*, 1958, **45**, May, 311–313). Several examples are given to demonstrate the feasibility of using this material for pattern making. In some cases stronger patterns can be made with this material than with ordinary timber.—L. J. L.

Using Synthetic Resins in Pattern Making. H. Kmoch. (*Giesserei*, 1958, **45**, Jan. 30, 72–74). Four different examples of the use of synthetic resins in pattern making are described. A description of the method used in each case is given. Typical cases used are for a water-cooled cylinder block and a water pump. A cost comparison is made between this method and that for patterns made of wood or metal.—R. J. W.

Pattern Design from the Point of View of Core Making and Casting. H.Kmoch. (*Giesserei*, 1958, **45**, May, 313–316). Foundry patterns should be designed so that core makers and moulders can produce cores and moulds with their aid rapidly and accurately. Practical hints on achieving this are given.—L. J. L.

The Manufacture of Box-less Patterns from Chemically Hardened Sands. M. Bednařik. (*Giessereitechn.*, 1958, **4**, April, 78–79). Chemically hardened sands are well suited to the mass production of small castings. The hardened moulds have great mechanical strength and can therefore be made thin. The preparation of moulds in presses or vibratory presses at the Foundry Research Institute at Brno, Czechoslovakia, is described.—L. J. L.

Standard Casting Boxes Serve to Raise Productivity. K.-H. Thiel and R. Holfeld. (*Giessereitechn.*, 1958, **4**, April, 83–85). At the moment it is difficult if not impossible to produce moulding boxes and accessories economically because of the enormous range of shapes and sizes. The advantages of standardization are pointed out. Existing East (TGL) and West (DIN) German standards are discussed.—L. J. L.

New Machines for the Production of Moulds and Cores in Foundries. E. Knipp. (*Demag News*, 1957, (147), 18–22). Filling and ramming machines are described and the Sandslinger is particularly referred to.

Moulding Machines. G. Somigli. (*Fonderia Ital.*, 1958, **7**, June, 217–227). [In Italian]. A wide range of plant and equipment used in modern mechanized foundries is described.

Some Aspects of Mould-Making. A. E. Peace. (*Brit. Found.*, 1958, **51**, May, 239–241). Presidential address to the annual general meeting.—T. G.

The Control of Oil Agglomerants for Foundry Sands. R. Cattaneo. (*Fonderia*, 1958, **7**, May, 201–208; June, 249–255). [In Italian]. The author classifies agglomerants by the chemical properties and by the technological characteristics which they impart to foundry sands. The effects of viscosity, specific weight, and iodine number are discussed.—M. D. J. B.

Experiments on the Preparation of Economical Croning Mould Binders. M. Lottermoser. (*Giesserei*, 1958, **45**, May, 304–307). The preparation of the moulds is briefly described; the properties of Duraplasts are discussed. Only phenolic resins have so far been used for the process; the suitability of aniline resins, aminoplasts, epoxide resins, and thiocols has been investigated. Combinations of certain types of fat pitch with elementary sulphur mixed with quartz sand proved to be suitable materials.—L. J. L.

On the Use of a Synthetic-Resin Core Binding Agent in the Steel Foundry. E. Lange. (*Giesserei*, 1958, **45**, Jan. 2, 22–23). The core-making process using a synthetic-resin core binding agent is described, particular reference being made to catalyst-controlled binding. Difficulties that must be overcome when introducing this process are described, but the economic advantages gained make this well worth while. Advantages of the method are listed and practical examples of its application given. A photograph shows a 25-t roll stand made by this process.—R. J. W.

Epoxy Resins for the Construction of Patterns and Core Boxes. (*Fonderia*, 1958, **7**, June, 265–268). [In Italian]. The thermoplastic properties of epoxy resins are briefly discussed and the methods of using these are reviewed.—M. D. J. B.

Alumina-Coated Silica-Sand Moulds for Heavy Steel Castings. B. Kőrös, I. Sidelszky, and F. Angyal. (*Koh. Lapok*, 1958, **13–9**, April, Öntöde, 95–97). The authors describe the production and properties of Al_2O_3-coated silica-sand moulds used in a Hungarian foundry for heavy steel castings.—P. K.

Production and Use of a Colloidal Graphite with Great Dispersion. G. Pávai, E. Grünwald, and J. Kertész. (*Koh. Lapok*, 1958, **13–9**, Öntöde, April, 85–90). The production and properties of a colloidal graphite with great dispersion, and its use for permanent mould dressing, are described.—P. K.

Economic Aspects of Some New Methods of Making Moulds for Light Grey-Iron Castings. M. Bednářik, S. Šimonik, and A. Šustek. (*Slévárenství*, 1958, **6**, (5), 137–142). The conditions under which the CO_2-process, shell moulding, or casting into metal moulds were most appropriate respectively were determined.—P. F.

Principles of the CO_2 Process. J. Leonard. (*Fonderie Belge*, 1958, June, 180–186). This is an abridged translation of a paper presented at the Stockholm Congress last September by Nield and Epstein, dealing with the principles on which the CO_2 process is based.

Mould and Core Production by the CO_2 Process at the Blakeborough Foundries. T. C. Wilson and J. B. Hollis. (*Brit. Found.*, 1958, **51**, May, 241–250). The application of the CO_2 process for moulds and cores for light and heavy castings is described. Sand mixes, effect of additions, blacking methods, gassing equipment and methods are described. A number of examples is quoted. The practical and economic advantages of the process are discussed and detailed analyses of labour and material costs included. The labour savings as compared with a mechanized foundry are up to 60% and with a heavy foundry up to 40%.—T. G.

Foundry Riser Cutting. (*Iron Steel*, 1958, **31**, May, 172). New riser cutting equipment supplied by British Oxygen Gases Ltd. results in a saving of time of up to 75% compared with hand-cutting. Brief details of the equipment are given.—G. F.

Mechanized Moulding Line Produces Grey Iron Brake Drums. R. H. Herrmann. (*Foundry*, 1958, **86**, July, 90–93). The moulding line consisting of two sets of rubber-diaphragm moulding machines and three sets of cope and drag machines—one of which is kept as a standby—is described. Back plates which are cast in are inserted into the mould by hand. Casting, cooling, shakeout are described.—T. G.

Moulding Machines. R. Hach. (*Technik*, 1958, Special Number, 177–183). A detailed review of machines shown at the Leipzig Fair.

Dry Binder Aids Core Baking. (*Iron Age*, 1958, **182**, July 24, 84–85). The use of glucose containing 6% $(NH_4)_2SO_4$ as catalyst is described. Time is reduced 30–50%.

Some Practical Experiences in Making Moulds in a Mechanised Foundry. H. Pinchin. (*Brit. Found.*, 1958, **51**, Apr., 182–193). The manufacture of moulds and cores in green sand by mechanical slinging methods at the Erewash Foundry of the Stanton Ironworks Co. Ltd. is described and discussed.—B. C. W.

Study on CO_2 Process Casting. I. Y. Mishima and K. Kobayashi. (*Ann. Rep. Eng. Res. Inst. Tokyo Univ.*, 1957, **16**, Sept., 115–118). [In Japanese]. By comparison with the shell moulding process, the CO_2 process of casting gives an inferior surface with pin-holes and other defects.—K. E. J.

Elimination of Porosity from Cylinders by the Use of Cores Containing Steel Grit. G. Blümel. (*Giessereitechn.*, 1958, **4**, May, 112). An account is given of a method adopted of adding steel grit (as used in the fettling plant), to parts of the core susceptible to porosity, in casting a cylinder. By this means a sound casting was produced.

Increasing the Yield in Finishing Castings in the Form of Rings or Plates. H. Kühne. (*Giessereitechn.*, 1958, **4**, May, 106–107). A note on improving casting design so as to reduce scrap, a gear blank being cited as an example.

Methods of Producing Internal Motion in Centrifugal Castings during Solidification. S. E. Rozenfel'd, S. B. Yudin and M. M. Levin. (*Lit. Proizv.*, 1957, (11), 24–26). Trials on 2 methods are reported with a Fe–Cr–Ni–Mo austenitic steel and comparisons with conventional castings. Castings were made either with a variable angular velocity, or at a low speed with an inclined or horizontal axis. The mechanism of the process is formulated and the products are described. The results are preliminary only.

How Fine Foundries Use Shell Moulding. R. H. Herrmann and J. C. Miske. (*Foundry*, 1958, **86**, Apr., 93–103). A description is given of the facilities and methods used to produce shell moulded castings at five American foundries.—B. C. W.

Shell Pattern Equipment Must Meet High Standards. R. Olson. (*Foundry*, 1958, **86**, Apr., 104–106). Some of the problems involved in designing and making shell moulding pattern equipment are discussed, and suggestions are made as to how foundrymen can help the patternmaker.—B. C. W.

Shell Moulding: Ten Years of Progress. (*Foundry*, 1958, **86**, Apr., 80–93). The answers received from foundries, resin manufacturers and equipment builders in response to questionnaires on the shell moulding process are summarized. The aspects covered include production methods, the need for new or improved materials and equipment, the possibilities of developing these, and the future of the shell moulding process.—B. C. W.

Modern Ironfounding Techniques. M. J. Glenny. (*Overseas Eng.*, 1958, **32**, Aug., 8–10). Shell moulding, the CO_2 process and investment casting are briefly described. Spheroidal iron is referred to and uses of cast iron for machine parts are discussed.

Investment Casting. (*Elect. J.*, 1958, **161**, Aug. 1, 296–297). The Mercast process is described.

The Interactions of Molten Metals and Refractory Materials. D. H. Houseman. (*Abstracts of Dissertations, Cambridge*, 1954–1955, 1957, 190–191). Penetration pressure was measured, and X-ray, metallographic and petrographic techniques were used, in the study of clay-bonded silica sand, showing the effect of ramming, and clay-bonded zircon by iron.

The Measurement and Effect of Grain Size in Steel Castings. W. J. Jackson. (*J. Brit. Steel Castings Res. Assoc.*, 1958, June, reprint. pp. 5). A critical literature review. Methods of examination are discussed, but the significance of grain size in castings remains to be determined. (19 references).

A Simple Guide to the Use of Exothermic Feeding Compounds in the Foundry. G. N. Cherry. (*Brit. Found.*, 1958, **51**, June, 303–307). The basic factors underlying the used of exothermic feeding compounds are explained and two new forms of exothermic material, exothermic moulding materials and flexible exothermic strip, are briefly described.

Preliminary Study of the Mode of Solidification of Chill Test Castings. I. C. H. Hughes. (*B.C.I.R.A.J.*, 1957, **7**, Aug., 10–22). Chill and mottle formation are discussed for simple castings and for the chill test casting which is shown to be complex. An attempt is made to explain in these terms the effect of pouring temperature upon chill, mottle formation and appearance of fracture.

Trials for the Elimination of Centre-Line Contraction Cavities in Steel Castings. H. Stein, F. Iske, and D. Karcher. (*Giesserei Techn. Wiss.*, 1958, **21**, July, 1115–1124). Published research on centre-line contraction cavities in steel castings were concerned with plates or bars, whereas the present authors made their studies on horizontally cast steel pipes. The results of the experiments, which are described in detail, show a dependence of the centre-line shrinkage cavities on carbon content and solidification range in a such manner that low-carbon steels give longer sound casting lengths than medium- and high-carbon steels. The effect of section size of the moulds on cavity formation was also studied and their chill effects determined.

A Note on the Influence of Furnace Holding Time on Chill and Mottle Formation. J. Rickard. (*B.C.I.R.A.J.*, 1957, **7**, Aug., 23–26). Depth of chill and of mottle increases with furnace holding time and mottle becomes coarser. Control of melting time and temperature is needed to regulate chill and mottle.

Surface Sinking Defects in Light Sectioned Grey Iron Castings. A. G. Fuller and I. C. H. Hughes. (*Castings*, 1958, **4**, June, 33, 35–48). All factors examined were found to influence the defect so that its occurrence is probably the consequence of a number of unfavourable variations occurring together. C, Si, P, Mn and S, effects of inoculation with graphitizing substances, pouring temperature, melting history, gating and design variables are all discussed. A list of 19 conclusions is given.

Some Factors Influencing the Incidence of Inverse Greyness in White Irons C. T. Moore. (*B.C.I.R.A.J.*, 1958, **7**, June, 262–267). Additions of B, Bi or Fe–Mn to the ladle and the effects of S content, Te mould wash and coal dust content of moulding sand on the incidence of inverse greyness in blackheart malleable iron have been studied and generally support previous findings that factors tending to reduce mottle also reduce the tendency to inverse greyness.

Dross Defects in Nodular Iron Castings. A. G. Fuller. (*B.C.I.R.A.J.*, 1958, **7**, June, 268–283). The effect appears to be due to segregation of a mixture of MgS–MgO and Al_2O_3 with oxides of Ca, Fe, Ni, Mn and Si. Ladle additions of Te and Ce greatly reduce the incidence of dross defects and on a long term basis careful control Al and Mg content is necessary. The coal dust content and moisture in greensand moulds, type of moulding material, type of inoculant, pouring temperature and gating systems also have an influence. Ni content appears to have no effect.

Errata

The Editor of *Liteinoe Proizvodstvo* has kindly drawn our attention to the following:

Vol. 189, June

p. 183*a*, 7th abstract, line 1 (and 183*b* line 3). For "Manganese" read "Magnesium."

p. 183*c*, 2nd abstract, line 2. For "**Ductile**" read "**Malleable.**"

p. 184*a*, 6th abstract. This is actually a special O.H. furnace process and the carburizing agent is coal.

Vol. 190, Dec.

442*b*, 1st abstract. This should read "**Automatic Mould Filling**", and the schemes are suggestions for the purpose of promoting discussion and have not been put into practice so that there are experimental results as yet.

442*c*, 7th abstract. The title should read: "**Low Silicon and Steelmaking Quality Pig Irons for High Quality Castings.**"

444*a*, 5th abstract, lines 2, 6 and 9. For "manganese" read "magnesium."

VACUUM METALLURGY

Vacuum Treatment of Acid Bessemer Steel. M. Solomonov. (*Izvest. Akad. Nauk Otdel. Tekh.*, 1958, (5), 144). Work carried out at the Baikov Metallurgical Institute and at the Dzerzhinsk plant showed that, with a residual pressure of 5 to 10 mm Hg column, 14 to 15 minutes' vacuum treatment ensures thorough deoxidation of the metal with carbon alone, which cannot be achieved even with diffusion oxidation. Oxygen content of the metal can be reduced to 0·0005 to 0·0007%. Rail steel of high strength and ductility is produced by vacuum treatment. An addition of 0·01 to 0·15% V raises the tensile strength by 20%. Good impact properties and resistance to ageing are attained by normalizing vacuum-treated acid Bessemer steel. Oxygen blowing of the hot metal is not necessary.—R. S.

Argo-Vac Vacuum Melting Furnace. (*Machinery*, 1958, **93**, Sept. 10, 601–604). A tilting furnace of 10–20 lb capacity is shown.

The Vacuum Casting of Steel. J. Levaux and M. Nepper. (*JISI*, 1959, **192**, May, 77–80). [This issue].

Vacuum Pour Giant Ingots To Make Flake-Free Forgings. (*Iron Age*, 1958, **182**, Oct. 30, 81–83). Vacuum pouring of ingots of up to 250 t weight at Bethlehem Steel Co. is described; plant, practice and advantages are dealt with. Vacuum is maintained by a four-stage steam-jet system. The product is notable for the absence of flakes and hydrogen embrittlement and the scarcity and small size of inclusions.—D. L. C. P.

Remelting Steels and Alloys in the Consumable Electrode Vacuum Furnace. G. N. Okorokov, A. Yu. Polyakov and A. M. Samarin. (*Izvest. Akad. Nauk Otdel. Tekh.*, 1958, (5), 59–62). The effect of consumable electrode vacuum melting on the properties of steels is discussed. The furnace and pumps are described. Ingots of 4 in. and 6 in. diameter were produced.—R. S.

Selective Volatilisation of Some Metals from the Surface of Steel During Vacuum Heating. S. F. Yur'ev and Z. I. Kuanitsina. (*Fiz. Met.*, 1958, **6**, (1), 157–. Surface changes associated with CrMn and CrNiMo steels after heating in the range 700–1200° C in a vacuum of the order of 10^{-4} mm Hg

column are determined. The nature of selective volatilization is related to properties and structure. Mn exhibited the greatest capacity for volatilization under the above conditions. Cr, Fe, Ni and especially Mo hardly volatilize at all. The extent to which a given component volatilizes in a multi-component system under the given conditions of vacuum and temperature is related to the vapour elasticity of the pure components.

REHEATING FURNACES AND SOAKING PITS

Heating Forging Billets. (*Met. Treatment*, 1958, **25**, Dec., 508). An account of the Birlec induction heating unit installed at the Witton (Birmingham) Works for operation at 700° C and 400 kW at mains frequency for preheating and at 3 kc/s for final heating is given.

Automatic Fuel Control. Plant for a New Continuous Bloom Re-Heating Furnace. (*Iron Steel*, 1958, **31**, Oct., 507–508). The automatic fuel control system in the bloom re-heating furnace put into operation in 1957 at the Cargo Fleet Ironworks of South Durham Steel & Iron Co., Ltd. is described.

Using Induction Heating Before Rolling the Blanks of Alloy Steels to Prevent Decarburising. K. F. Starodubov, A. F. Tegubenko, S. Z. Yudovich, B. P. Kolesnik, and M. I. Lobarev. (*Stal', Supplement Metallogr. and Heat treatmt.*, 1958, 39–49). An apparatus using two frequencies is proposed for heating blanks of ferro-magnetic materials. For heating below the magnetic transformation, approximately 50 cycles and for higher temperatures approximately 500. The experiments have proved that with this method practically no decarburizing takes place. The method is recommended for industrial application.—L. H.

Heat Billets With Molten Glass. (*Iron Age*, 1958, **182**, Aug. 14, 87). A new type of furnace is described which heats billets for extrusion. A rotating gas-fired furnace contains molten glass; the billets, pre-heated by the waste gases, are rapidly heated in the furnace. Capacity of the existing furnace is 1000 lb/h. Advantages include speed, capacity, fuel savings, de-scaling and protection of billets, low maintenance costs. It has also been found useful for heating high-temperature alloys. **Glass Bath Heats Forging Billets.** (*Steel*, 1958, **143**, Aug. 11, 74).

High-Intensity Oil Combustion. W. K. Etchells. (*Met. Treatment*, 1958, **25**, Dec., 515–517). A report of a lecture. Uses in forge furnaces, heat-treatment and galvanizing of burners for light fuel oil are indicated.

New Plant for Refractory Metals Will Feature Inert Atmosphere. (*Iron Age*, 1958, **182**, Nov. 13, 148–149). A plant under construction will provide facilities for a new technique known as "IN-FAB" for producing parts in metals such as Mo, Cb, W, Re, Ta. The plant consists of an airtight enclosure measuring 40 × 80 × 25 ft, in which a high purity argon atmosphere can be maintained; equipment inside may include induction heaters, an impactor for making billets and sheet bar, rolls, metalworking and welding machines. Operators in the enclosure will wear 'space-suits.'—D. L. C. P.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

Erratum

1958, **190**, Dec., p. 446*a* line 3. For "73-84 Tons/Sq. in," read "33–38 Tons/sq. in."

A New Combustion Process for Temperature Uniformity in Heat Treating Furnaces. F. C. T. Daniels and S. Stasko. (*Iron Steel Eng.*, 1958, **35**, July, 85–91). To obviate local high and low temperature zones, a combustion system has been designed in which excess of air is used, together with suitable location of the burners. Temperature variations have been greatly reduced. Application of the process to several types of heat treatment furnace is discussed.

Modern Tendencies in the Design of Oil-Fired Industrial Furnaces. M. Moreno Baez. (*Ing. e. Indust.*, 1957, **25**, Dec., 88–91, 101). [In Spanish]. The principles underlying improvements in oil-fired heat-treatment furnaces are illustrated and discussed under the following headings: use of heavy fuel oils; use of multiple burners; atmosphere control; gas recirculation by fans, thermal syphons, air or burner induction; outer coverings; use of insulation; recuperation.—P. S.

Heat Treatment of Drop Forgings. F. C. Bird. (*Met. Treatment*, 1958, **25**, Dec., 518–520, 525). Synopsis of one of the NADFS Spring lectures illustrated with films.

Improved Heat-Treating Processes for Large Forgings. N. V. Fiksen. (*Metallav. Obra. Met.*, 1957, Nov., 77–80). Shortening of the time taken is sought, large blooms often taking 15–20 days. Rolls of steels 55 Kh, 60 KhG and 50G low-alloy steels can now be treated in 160 h instead of 300 h and the properties across the 1 m diameter are shown. Arrangements have also been made for quicker transfer from furnace to furnace while hot. Induction hardening of large rolls has also been developed. Isothermal annealing methods to avoid flaking have also been evolved.

Controlled Atmospheres. P. F. Hancock. (*Met. Treatment*, 1958, **25**, Aug., 323–330). Composition, methods of generation and applications of controlled furnace atmospheres are described.

Atmosphere Protects Finish. (*Steel*, 1958, **143**, Aug. 11, 80). The equipment described allows titanium, stainless steel and other metal parts to be heat treated and quenched, while protected from oxidation by an argon or helium atmosphere.—D. L. C. P.

Large-scale Continuous Annealing of Coils with Carbon Restoration. J. D. Armour. (*Wire Wire Prod.*, 1958, **33**, June, 655–657; 700–701). A continuous pusher tray type furnace is described having atmosphere control suitable for the treatment of cold forming and automatic machining stock without surface decarburization. The atmosphere consists principally of NX and RX generator gas with small amounts of natural gas.

Anneal Stainless Tubing For Corrosive Use. J. S. Adelson. (*Iron Age*, 1958, **182**, Aug. 7, 83–85). The causes of failure in stainless tubing are discussed. Annealing is recommended for welded tubes which have to withstand corrosion.—A. G.

Temperature Distribution Throughout a Stack of Electrical Sheet Steel during Annealing. R. J. Wakelin. (*Brit. J. Appl. Phys.*, 1958, **9**, Sept., 353–358). Theoretical calculations were made for 8 ft × 3 ft × 0·014 in. 4%Si electrical sheet and compared with experimental findings. The distribution within the stack was obtained for all times during the 3-day annealing cycle at ~ 800° max.

New Thermo-chemical Techniques. I. Bright Annealing. P. Galmiche. (*Met. Treatment*, 1958, **25**, Oct., 405–408). The process is described and examples are given.

Effect of Homogenising on the Stability of Undercooled Austenite in CrNiMo Steel. I. E. Brainin, A. I. Kondrashov and V. A. Kharchenko. (*Izvest. Akad. Nauk, Otdel. Tekh.*, 1958, (5), 54–58). Diffusion annealing of forged CrNiMo steel at 1200–1255° C considerably reduces the period of austenite breakdown in the upper and intermediate sub-critical zones. Isothermal treatment of undercooled austenite in CrNiMo steels in the 300° C region must ensure the complete breakdown of austenite.—R. S.

Lead Patenting of High-Carbon Steel Rod and Wire. R. H. Hertzog. (*Wire Wire Prod.*, 1958, **33**, Oct., 1176–1177, 1288–1289). The issue is discussed as to whether to base lead-patenting practice on a constant lead bath temperature or on a variable temperature adjusted to give a tensile strength that varies only with carbon content. Extensive works investigations at John A. Roebling's Sons Corp., New Jersey, have favoured the latter course, with temperatures established for ranges of carbon content and rod or wire sizes. These are quoted, and the average curve of tensile strength *v.* carbon content is presented for one lead quench temperature and rod size.—J. G. W.

Process Speeds Strip Annealing In Liquid Sodium. (*Iron Age*, 1958, **182**, Nov. 6, 108–109). A new process for annealing steel strip is described. Strip is progressively heated and cooled between 300° and 1350° F in a liquid Na bath. The heat-transfer rate is very high so that fuel consumption is low and the plant is compact—a strip travel of 30 ft should allow as high a production rate as from 2100 ft of passes through a conventional furnace. Quality of annealed strip is not impaired by the short annealing time of a few seconds.—D. L. C. P.

Using the Normalising Heat to Prevent Flakes in Rails and Improve Simultaneously Ductility and Tensile Strength. P. T. Besedin. (*Stal', Supplt. Metallogr. and Heat Treatmt*; 1958, 229–239). Investigations of specimen rails of type R50 and R43 rolled from steels blown in the moulds with oxygen have shown that provided the temperatures of normalizing and hardening are adjusted according to the results of the experiments to correspond to the requirements of the individual steels, it is possible to avoid flake formation and to obtain an improvement in the physical characteristics of these rails.—L. H.

Studies on the Kinetics of Very Rapid Cooling in Different Quenching Liquids: Application to Some Alloys of Iron, Nickel and Carbon. R. Faivre and R. Bigot. (*Nat. Metallurgical Lab. Council of Sci. and Ind Res., Jamshedpur*, 1958, 362–373). Rates of cooling in various media, structures produced and applications are discussed. (22 refs.).

Quenching Tanks, Fire-risks and the Modern Answers. (*Iron Steel*, 1958, **31**, Sept., 462). To combat the fire risk of oil quenching tanks a new type of portable dry powder extinguisher is stated to offer many advantages.—A. G.

Tempering of Steels. A. B. Chatterjea. (*Tisco*, 1958, **5**, July, 129–138). The phase changes taking place on tempering plain carbon and alloy steels, the effect of alloying additions on hardness when tempering, time and temperature relationships and the mechanism of secondary hardening are discussed. (34 refs.).

I.C.I. Automatic Austempering Plant for Imperial Typewriter Components. ((*Machinery*, 1958, **93**, Nov. 5, 1046–1050). An illustrated description of a plant installed at Hull.

Chilled Iron Rolls: Production at Thomas Robinson & Sons, Ltd. T. Kneale. (*Iron Steel*, 1958, **31**, July, 351–354). The production of chill iron rolls having a surface hardness of 500–520 Brinell for flour grinding is described. High-quality finish is due to an ideal composition of the metal and to the special moulding techniques. The transition from the chill to the softer and tougher core is smooth and eliminates flaking in use.—T. G.

Non-Deformation Tempering of High Speed Steel Tools. Hsu Tzy-Yao. (*Chinese J. Mech. Eng.*, 1958, **6**, (3), 203–206). The stabilization and isothermal transformation of the residual austenite retained in tempering to bainite, will take place in high speed steels by keeping them for a certain time below a definite temperature. The saturated degree of stabilization, the incubation period and the isothermal transformation during exposure to heat as well as the residual austenite at room temperature have been measured during cooling and the results tabulated. These will serve as a reference for selecting the heat treatment for non-deformation tempering.

FORGING, STAMPING, DRAWING, AND PRESSING

Guide to Forging Methods. (*Iron Age*, 1958, **182**, Aug. 21, 93–95). The characteristics of the following forging methods are described: smith, drop, machine (or upset) and press.—D. L. C. P.

Opening of a New Light Forge. (*Mech. Handling*, 1958, **45**, Dec., 822–824). An account of the Hales Owen works installation with descriptions of the items of equipment including furnaces, presses and manipulator, rotary table and charging machine.

Light Steel Forgings. (*Engineering*, 1958, **186**, Oct. 31, 578–579). An account of operations at Walter Somers Ltd., Haywood Forge, Hales Owen with a list of equipment and a brief account of operation.

Choice of Steel for Forgings. (*Iron Age*, **182**, Aug. 21, 96–97). The properties of a wide range of steels are considered in order to illustrate their forgeability and applications.

Why Buy Steel Forgings? (*Iron Age*, 1958, **182**, Aug. 21, 90–92). The production and properties of steel forgings are surveyed, with a view to illustrating suitable applications. Forgings are notable for strength, soundness, metal economy, ease of inspection, response to heat treatment and ease of welding.

Metal Flow in Forging. VIII. Design and Manfuacture of Ball Rolling Die. T. Awano and M. Ochiai. (*Rep. Gov. Ind. Res. Inst.*, 1958, **7**, Sept., 631–637). [In Japanese]. Forms of dies for continuous rolling of balls are calculated, and design information is given for ratios of die/ball dia. of 3 to 15. An attachment to a lathe having a cam mechanism for cutting the rolling dies is described.

Gear Forging Advances. (*Steel*, 1958, **143**, Sept. 8, 100–101). Close tolerance insert forging dies produce gears which do not require machining. These dies have a relatively short life, but can be reconditioned at low cost.

Tool Steel Bows to Deep Drawing. P. M. Unterweiser. (*Iron Age*, 1958, **182**, Sept. 18, 83–85). An account is given of the successful deep-drawing of a 5%Cr tool steel at room temperatures. Close control of the process and material quality are essential.—A. G.

Combined Hot Forging and Cold Forming Produces 8 in. Shells. (*Metalw. Prod.*, 1958, **102**, Dec. 19, 2220–2221). The process carried out by the American Car and Foundry Division of ACF Industries is outlined. **Hot-Cold Forming Boosts Quality, Prunes Costs.** (*Steel*, 1958, **143**, Nov. 3, 72–74). The method and advantages of producing 8 in. howitzer shells by a combination of the hot cup and cold-draw processes are described. The conventional method is hot forging and machining with heat treatment to get the necessary mechanical properties. The advantages are: (1) less starting material required; (2) lower carbon steel can be used; (3) no quenching or tempering required; (4) less machining needed; (5) possibility of mechanization reduces manhours 50%; (6) improved quality.—D. L. C. P.

Bishop Broadens Range of 17-7 PH. (*Steel*, 1958, **143**, Aug. 25, 94–96). The re-drawing of 17-7 PH alloy steel normally spoils the properties that make it respond to heat treatment; it is reported that one company has overcome this difficulty. By special drawing techniques and closely controlled annealing cycles, solution annealed small diameter tubes are produced that will respond fully to heat treatment. Seamless tubes down to 0·375 in. diameter, 0·035 in. wall can be made.—D. L. C. P.

Shot Peening and the Use of Steel Wire Slugs, W. Gesell. (*Wire*, 1958, June, 26–27). Considerations governing the use of wire slugs in shot peening are briefly reviewed, including properties and dimensions of the slugs, jet intensity and duration of treatment.

The Fundamentals of Wire Drawing. J. G. Wistreich. (*Met. Rev.*, 1958, **3**, (10), 97–142). A general discussion is presented with special reference to practical conditions. Temperature, friction, die wear lubrication effects and wire properties are all considered. (93 refs.).

New Wire Mill Opened in Sheffield. (*Wire Ind.*, 1958, **25**, June, 545–547). The Kingfield Works of Darwins Bright Steels Ltd., is described.—J. G. W.

Planning and Building a New Wire Mill in Manchester. (*Wire Ind.*, 1958, **25**, June, 558–559). The new works of A. C. Scott and Co., Ltd., makers of resistance and thermo-couple wires, and briefly described.

Wire-Drawing Shop Practice: High Quality at Darwins Bright Steels, Ltd. (*Iron Steel*, 1958, **31**, July, 345–349). Layout and operation of the Kingfield works, that started production recently, are described. Quality control is dealt with and a plant schedule of the five bays is described in detail in an Appendix.—T. G.

Wire Rolling and Forming Tool Applications. K. P. Lovdahl. (*Wire Wire Prod.*, 1958, **33**, May, 534–535). Tooling for the rolling of shaped wire is described, particulars being given of the tool materials and the grinding technique for the rolls.—J. G. W.

Nomograms for Drawing Force and Power Consumption in Wire Drawing. (*Wire*, 1958, June, 31–36). The nomograms presented here are based on formulæ by Pomp and Lueg and Haas, with approximations introduced the accuracy of which is unknown, and by employing a weighted mean yield stress.—J. G. W.

Some Limiting Factors in Extrusion. S. Hirst and D. H. Ursell. (*Met. Treatment*, 1958, **25**, Oct., 409–413, 416). A comparison of lubricated and unlubricated extrusion is made, the theory of plastic deformation being formulated in terms of pressure and incipient melting limiting curves. The examples are non-ferrous.

Steel Extrusions Minimize Machining. (*Metalw. Prodn.*, 1958, **102**, Oct. 24, 1879–1880). The process used at Low Moor under licence is described.

Impact Extrusion of Steel Wrist Pins. (*Prec. Met. Mold.*, 1958, **16**, Oct., 40–42). The Ford Motor Co. process is described using AISI 5015 steel, which is hardened after extrusion by core carburizing in a 3-zone Holcroft furnace, quenched in a phosphate solution and tempered at 375° F for 1 h. Structure is shown.

ROLLING MILL PRACTICE

Study of Ultra-Thin Tapes of 50% Fe–Ni Alloys (2nd Report). The Rolling and Recrystallization Textures of the Ultra-Thin Tapes. E. Tanaka and H. Katô. (*Nippon Kinzoku*, 1958, **22**, Jan., 30–33). It was found that 50% Fe-Ni alloy magnetic tape less than 0·01 mm thick had inferior magnetic properties, and these were associated with a less clearly defined texture.—J. G. W.

Rolling Mill Practice. H. Sedlaczek and A. Wolf. *V.D.I.Z.*, 1958, **100**, Oct. 21, 1469–1474). A review is presented of the literature published in 1957 and 1958 on the rolling process, roll pass design, hot rolling, and cold rolling.—L. J. L.

Comparison of Russian Methods of Calculating Loads in the Hot Rolling of Steels. Z. Wusatowski. (**Zeszyty Naukowe Pol. Sl. Mechanika*, 1956, (3), 19–46). A comparison of the methods of Tselikov, Gubkin, Golovin and Tyagunov, Golovin and Shveikin, and Samarin is made on data from plate, sheet, and blooming mills and from large and small rolling mills. Tselikov's methods are found to give fairly good results for sheet mills, but the later methods are better though the values they give are usually too low, especially for strip mills. The value of the methods is indicated for the various types of mills. Gubkin's expressions are not suitable for practical application, being derived from drop-forging, but for plate rolling, Samarin's method, for very thin sheets, Golovin-Tyagunov's, for large strip mills, Samarin's and for small rolling mills Golovin-Tyagunov's would be preferred, but the actual order is given in each case.

Hot Rolling of Steel 35 with High Draughts. Z. Wusatowski, W. Gorecki, E. Judycki and F. Wiacek. (*Prace Inst. Hutn.*, 1958, **10**, (4), 185–198). New relationships for coefficient of spread and elongation were obtained with experimental reductions of 50–90%. An expression for forward slip, the calculation of the non-slip angle, and roll pressures were also obtained. Calculated values from eight published expressions were compared.

Determination by Experiment and by Calculation of Roll Force and Torque Taking Strip Tension into Account. H. G. Müller and P. Funke, jun. (*Stahl Eisen*, 1958, **78**, Oct. 30, 1564–1574). Tests on a small laboratory 12-roll Rohn mill showed that the formulæ given in the literature for calculation of the roll force are sufficiently accurate; the prediction of the torque is, however, still difficult as the equations quoted in the literature are not in agreement with experimental results. Published work is reviewed and the experiments are reported in detail.—T. G.

Cast Rolls. (*Engineering*, 1958, **186**, Oct. 17, 520–521). Casting and finishing practice at the works of Johnsons Rolls Ltd., West Bromwich is described.

Casting Rolls of Nodular Iron at the "Vlahuta" Plant. M. Hirsulescu and M. Dala. (*Met. Constr. Masini*, 1958, **10**, (7), 570–572). [In Rumanian]. For the time being only rolls for sheet rolling and light profiles are cast in nodular iron. It is hoped that rolls for heavier work will follow. The iron is obtained by addition of electrode ends (Mg–Al alloy) to the ladle of molten iron as poured from the cupola, together with 0·5% ferro-silicon (75%Si). Contents are calculated from the liquid weight in the ladle. Casting temperature had to be raised to 1420–1430°. The final procedure after numerous adjustments, has succeeded in obtaining a current production of cast rolls with a hard surface, and tests are now in progress to establish the service life of these rolls.—L. H.

Punch Cards Lead Drive to Automatic Mill Control. G. J. McManus. (*Iron Age*, 1958, **182**, Sept. 11, 169–171). Punch card control systems are being installed on 15 rolling mills. To date no startling improvements have been achieved and further progress awaits instrumentation to measure such variables as slab plasticity and steel flow.—A. G.

Card Programming Control of Rolling Mills. Part I. R. W. Holman. (*Iron Steel Eng.*, 1958, **35**, June, 113–114). This paper describes the progress made at U.S. Steel Corp. in numerical control applications to industrial operations and more specifically to rolling mills. **Part II.** R. G. Beadle and W. E. Miller. (115–119). The authors describe punched card preset screw-down control on the reversing roughing mill at The Allegheny Ludlum Steel Corp. Details of the equipment, its operation and the results achieved are described.—M. D. J. B.

Width Meters Trim Strip Waste. (*Steel*, 1958, **143**, Oct. 20, 182–185). A BISRA width gauge installed on a Morgan mill rolling narrow strip is described. Unlike other meters this does not rely on radiation from the strip. Such gauges permit closer tolerances and can save 1% of the coil weight.

Translator Control in Steel Rolling Mills. W. N. Jenkins. (*New Sci.*, 1958, **4**, Oct. 30, 1149–1151). A popular account of the BISRA system.

Automatic Gauge Control. M. F. Dowding and R. B. Sims. (*United Nations, E/ECE/306; E/ECE/Steel/119*, 1958, 103–107). Progress in rolling mill instrumentation and control is indicated.

The Use of Baffle Plates Instead of Suspended Guides. I. T. Lyzhenko. (*Metallurg*, (9), 28). The use of a fixed baffle plate above the exit guide in a 32-in. finishing stand reduced breakages of guides and cobbling.—R. S.

Cold-Rolling Plant for Brinsworth Mill. (*Sheet Metal Ind.*, 1958, **35**, Aug., 622). The existing Brinsworth continuous medium-width hot-strip mill will be augmented by a tandem cold-rolling mill and a skin-pass mill for strip 18 in. wide and 0·010–0·25 in. thick. The throughput will be about 2000-t per week. At the Scunthorpe works the new four-high steel plate rolling mill with a throughput of initially 9000-t per week has started production.—T. G.

Hardening of Steel by Cold Rolling. N. Bogoevici. (*Met. Constr. Masini*, 1958, **10**, (7), 561–562). [In Rumanian]. Since rolling is a compression process, it would be more appropriate if investigations into this type of hardening were based on the behaviour of metals under compression and not under tension, because there are appreciable differences in behaviour. This must be studied in order to obtain the optimum conditions for the operation.—L. H.

An Automatic Gauge Control System for Tandem Cold Mills. N. S. Walker, J. W. Cook, and J. W. Wallace. (*Iron Steel Eng.*, 1958, **35**, July, 124–132). An automatic

gauge control system, based on the adjustment of tension between stands is described in detail, and results discussed. The use of an analogue computer in design and development work is mentioned. A complete system utilizing both tension and screwdown control is also outlined.

Jones and Laughlin Rounds Out Expansion at Aliquippa Plant. (*Iron Steel Eng.*, 1958, **35**, Aug., 138, 140). The second of two modern continuous weld tube mills at the Aliquippa plant is now in operation. The capacity and operation of the two plants are described.

An Analysis of Existing Methods for Calculating the Profile of the Rolls of Cold Tube Reducing Mills. Yu. F. Shevakin. (*'Stal', Rolling and Tube Manufacture Supplement*, 1958, 259–275). The problem as to whether the design should follow a smooth curve or should take into account the change in plasticity of the material is discussed. The formulæ for the two cases are given and curves for change in pressure along the grooves are shown. The measurements were in agreement with the theoretical analysis and a general equation for change of area of cross-section of the tube along the working cone is given.

Operational Experience with an Automated 16-in. Tube Mill. I. G. Mindlin. (*Metallurg*, 1958, (9), 29–31). Production of tubes in the recently automated tube mill at the Zakavkaz plant is described.—R. S.

Mill Gearing as Viewed by a Lubrication Engineer. A. E. Cichelli. (*Iron Steel Eng.*, 1958, **35**, Sept., 91–102). The author reviews various aspects of mill gearing design, metallurgy and lubrication, illustrating his conclusions by a number of case histories. Lubrication may be a minor factor affecting gear life, and is no substitute for good geometry and metallurgy. In steel mill gearing it is thought possible that Buckingham's wear load limit should be 1·5 times the anticipated dynamic load.

Mill Drive Motor Line Incorporates Advanced Features. (*Iron Steel Eng.*, 1958, **35**, Sept., 207–208). The new standard motor line developed by G.E.C. is designed to reduce maintenance. Details of improvements are given.

Bar and Tube Straightening Machines. E. L. Tinley. (*Iron Steel*, 1958, **31**, July, 373–374; *Engineering*, 1958, **186**, Nov. 14, 625–629). Design and operation of modern straightening machines are described and the essential features pointed out. The material is passed between rolls of concave contour, oppositely inclined on either side of pass. Modern machines have now three pairs of driven cross rolls. The benefits of driving all rolls are elimination of roll skid, resulting in reduced roll wear and a capacity for straightening very thin wall tubes.—T. G.

Determination of the Safety Factor of Rolling Mill Parts by Means of the Cast Iron Safety Pot-Shaped Pad. W. Dobrucki. (*Hutnik*, 1958, **25**, (7–8), 384–391). The accident that happened in one of the sheet rolling mills, three-high type, is described. The transmission gear had been damaged due to the excessive thickness of a sheet in the pass. The role and work of a safety pot-shaped pad is discussed; the fact that it does not prevent the occurrence of excessive torques in gear is emphasized. The absence of theoretical investigations and experimental data for calculating these pads is stated. The desire is expressed that thorough theoretical and experimental investigations of safety devices for rolling mills should be undertaken.—S. S.

Ending Machines in Light-Section Rolling Mills. F. Greuel. (*V.D.I.Z.*, 1958, **100**, Oct. 21, 1444–1453). Ending machines are described, with emphasis on automation and mechanization, under the following heads: cropping machine, bundling devices, levelling installations, and weighing machines.—L. J. L.

MACHINERY AND SERVICES FOR IRON AND STEEL PLANT

Handling of Steel Plate. (*Machinery Lloyd*, 1958, **30**, Oct, 25, 80–81). [In English and Spanish]. Electromagnet design is briefly referred to.

Storing Large Steel Sections. K. Mumby. (*Mech. Handling*, 1958, **45**, Nov., 720–724). Storage in stillages and racking and handling with special grabs at the G.E.C. Witton works, is described.

Factors in the Design of a Steel Plant Power System. A. J. F. MacQueen. (*Iron Steel Eng.*, 1958, **35**, Oct., 93–100). An outline of the power requirements of an integrated steel plant is given, with a discussion of some of the load characteristics and plant conditions to be met.

Power Distribution at Vancoram Plant, Vanadium Corporation of America. F. G. Fellows and H. F. White. (*Blast Fur. Steel Plant*, 1958, **46**, Sept., 968–970, 973). The power distribution for this Ohio ferro-alloy plant, which uses a number of electric furnaces, is described.

The Application of Silicon and Germanium Power Rectifiers in the Steel Industry. R. J. Moran. (*Iron Steel Eng.*, 1958, **35**, Aug., 117–122). Ge and Si are more efficient than CuO and Se, and are not subject to ageing. They are suitable for steel mill service; Ge is more suitable for applications below 35V, and Si for use at medium and high voltage. Some applications and circuit diagrams are given.—L. D. H.

Electronics in the Steelworks. J. K. Edwards. (*Elect. Rev.*, 1958, **163**, Nov. 14, 897–903). The need for reliability is noted, but demands are being met. The use of the mercury arc rectifier, instrumentation in rolling mills, photocell uses, thickness gauging, and quantometer analysis are briefly considered and possible future uses are mentioned.

How Computers Will Help Steelmakers. M. Phister jun. (*Steel*, **143**, Nov. 10, 126–129). The type of work which can be done by digital computers is described, and possible applications of these machines in steelworks are considered. The computers can collect information from process instruments, store information, do calculations and then make decisions and give out information in printed or controlling form. Thus plant such as coke-ovens, blast furnaces, open hearths, soaking pits and rolling mills could be continuously controlled to operate at optimum conditions.

Mechanical Marshalling of Railway Wagons in Works Sidings. G. W. Grossmith. (*Chartered Mech. Eng.*, 1958, **5**, Nov., 414–416).

Collector Handles Mill Scale on Continuous Basis. J. A. Lowry. (*Iron Age*, 1958, **182**, Nov. 20, 106–107). A unit reclaiming 12–15 t/h is briefly described.

Modern Sluiceway Design Removes Mill Scale. (*Iron Steel Eng.*, 1958, **35**, Oct., 165–166). The sluicing system installed at the hot strip mill at the Weirton Division of the National Steel Corp. uses relatively low volumes of water at high pressures. The operation of the system is described.

WELDING AND FLAME-CUTTING

A.W.S. Bibliographies. (*American Welding Society*, A7.0–58, 1958). Bibliographies of articles appearing in the *Welding J.* since 1937 are presented in chronological order on the welding of aircraft (pp. 5); of cast iron (pp. 3); on brazing, (pp. 5); on destructive examination in welding (pp. 13); on electrodes and welding rods (pp. 8); on flame hardening and flame softening (pp. 3); on inert-gas metal-arc welding (pp. 9); on inspection and non-destructive examination (pp. 5); on welded machinery construction (pp. 3); on metallizing (pp. 2); on oxygen cutting, gouging and machining (pp. 5); on piping and tubing (pp. 7); on welding applications in the railroad industry (pp. 4); on pressure vessels including storage tanks (pp. 7); on resistance welding (pp. 13); on safety in welding (pp. 3); with a list of safety bulletins (1 p.); on welding in ship construction (pp. 6); on stainless steel (pp. 7); on structural welding (pp. 8); on submerged arc welding (pp. 5); on surfacing (pp. 4); on the training and qualification of welders (pp. 3) and on various non-ferrous metals.

Progress in the Welding of Steels. G. Grenier. (*Echo Mines*, 1958, Aug., 489–491; Sept., 537–539). A general review. (14 refs.).

The Utilisation of the Iron-Carbon-Diagram in Welding Technology. F.-C. Althof and G. Hoffmann. (*Schweisstechn.*, 1958, **12**, Aug., 105–112). The construction of the Fe–C diagram and the effects of temperature and duration, of ageing, isothermal conversion, and recrystallization are discussed. Insert fusion welding is used to illustrate the various types of structure due to differences in heating and cooling.—L. J. L.

Materials Selector: Joining and Fastening of Materials. (*Mat. Design Eng.*, 1958–59 *Reference Issue*, **48**, Mid-Oct., 372–393). Brazing and soldering alloys and welding rods, adhesives and mechanical fastenings are listed with annotations.

How to Make Machinable Welds in Cast Iron. (*Usine Nouvelle*, 1958, **14**, Aug. 7, 28; from *Machine Moderne*, March). Suitable choice of welding rod and of method of welding can give a machinable weld. Factors are discussed.

Welding Low-Alloy Steel Castings. N. A. Chapin, C. H. Soldan and L. W. Songer. (*A.S.M.E. preprint*, 58-Met-4, 1958, pp. 11). The welding of castings for service at high pressures and high temp. is reviewed. Steam turbine-generator components processed and submerged-arc welded are described and heat treatment, casting and fabrication design are discussed.

Reactions of Silicon and Manganese in Submerged Arc Welding of Low-Carbon Steel. K. V. Lyubavskii. (*Avtogennoe Delo*, 1947, **18**, (7), 1–10). Effects of flux and parent and electrode metal compositions, passive and active fluxes, and control of silicate inclusions are discussed.

Contribution to the Problem of Obtaining Welded Joints of Unstabilised Steels of the 18/8 Cr–Ni Type which Are Resistant to Intercrystalline Corrosion. J. Němec. (*Schweisstechn.*, 1958, **12**, Sept., 121–126). Experiments in the water-cooling of manually arc-welded joints of 18/8 steel, provided that the water was applied immediately behind the arc, showed that intercrystalline corrosion could be greatly diminished, although not completely eliminated with Mo-free steels containing 0·08–0·10%C. No great improvement was obtained with 0·11%C steels. Water cooling is an additional complication, and its use is justified only in certain cases.

Automatic Welding of Stainless Clad Material. (*Weld. Met. Fabr.*, 1958, **26**, Aug., 277). Fabrication of large tanks is described.

The Welding of Special and Alloy Steels. J. Hinde. (*Nat. Metallurgical Lab., Council of Sci. and Ind. Res., Jamshedpur*, 1958, 401–413). Corrosion-resisting steels, ferritic and austenitic and copper-bearing mild steel, low-alloy-high-tensile steels and low-temperature and high-temperature creep-resisting steels are tabulated and discussed. (30 refs.).

Fabrication and Inspection of Alloy Steel Piping. W. W. Offner. (476–484). Tungsten-arc inert-gas welding of steel pipe is described. X-ray and other testing methods are briefly dealt with.

Welding Type 347 Stainless Steel Piping and Tubing. G. E. Linnert. (*Weld. Res. Council, Bull. Series*, 43, 1958, Oct., pp. 103). A comprehensive report including previously unpublished data. The origin and development, composition, microstructure and properties of wrought and cast material and of the weld metal are given. Welding procedures and joint properties are given at length and defects are discussed, both cause and cure. Uses and preformance in service are also described.

Welding Repairs to Railway Locomotives. R. D. Gemmell. (*Eng. Foundryman*, 1958, **23**, July, 67–73).

Enclosed Welding of Rail Sections. G. Zoethout. (*Philips Techn. Rev.*, 1958/59, **20**, (4), 94–100). A method of welding *in situ* is described.

A Welding Method for Steel Pressure Vessels for Atomic Energy Applications: Argon Arc Welding with a Consumable Electrode. J. Tigeot. (*Soud. Techn. Connexes*, 1958, **12**, Sept.-Oct., 325–335). When carbon steels are

subjected to neutron irradiation the transformation temperature tends to rise. Argon arc welding with a consumable electrode gives the weld metal good impact values, making it suitable for the construction of nuclear reactor vessels up to at least 15 cm thick. The costs are slightly higher than for submerged arc welding, but justifiably so. The apparatus and technique are described.

Induction Brazing Overcomes Distortion of Fabricated Carbine Barrel Casings. P. Trippe (*Metalw. Prod.*, 1958, **102**, Dec. 26, 2255–2257). An illustrated description. Brazing takes 60–70 sec.

The Contribution of Brazing in Light Engineering. E. V. Beatson. (*Machinery*, 1958, **93**, Aug. 27, 473–481). A review of processes and choice of alloy for stainless steel and Nimonic alloys and of high-frequency and resistance methods is presented.

Die-Cut Adhesive Film Bonds Iron to Aluminium. (*Iron Age*, 1958, **182**, Oct. 30, 88–89). The bonding of a powdered iron disc and a die-cast Al plate to form a rotor end-plate is described. A thin sheet of a "nitride" phenolic adhesive is placed between the 2 parts and the assembly is cured under pressure.

The Adhesion of Metals. G. Kargl. (*Maschinenwelt Elek.*, 1958, **13**, Sept., 322–326). The general principles, types of binder, treatment of the material, applications and strength characteristics of the bonded products are outlined, the examples given being non-ferrous parts used in aircraft construction.

Torches Machine Big Forgings To Near Finished Size. G. J. Gilhorn. (*Iron Age*, 1958, **182**, July 10, 108–109). Examples are given of cases in which flame cutting has saved considerable time over machining, for roughing out large shapes. One example describes the slicing of multiple ring forgings on a turntable; the torches can also cut chamfers inside and outside the rings.—D. L. C. P.

Powder-Cutting of Stainless Steel. A. L. Chappell. (*Weld. Met. Fab.*, 1958, **26**, Nov., 403–404). A new machine with a cutting area 27 × 42 ft used for slabs up to 45 in. wide and 6 in. thick has been installed by the English Steel Corp. Designated COT 1, it is illustrated and described.

Application of the Numerical Analogue System to Oxygen Cutting Machines. L. J. Hancock and J. R. Arrowsmith. (*Brit. Weld. J.*, 1958, **5**, Aug., 369–373).

Gas Cutting Shows Benefits Over Acetylene. (*Western Metalw.*, 1958, **16**, Aug., 43–44). Natural gas cutting of steel plate in a Los Angeles works is briefly described.

Development of the Tungsten-Arc Cutting Process. R. A. Cresswell. (*Brit. Weld. J.*, 1958, **5**, Aug., 346–355). Equipment and the results of cutting stainless steel and other metals are described. The cut surfaces are ready for welding without further preparation. Health hazards are noted and simple safety precautions are given.

MACHINING AND MACHINABILITY

Mechanics of Orthogonal Machining. W. B. Palmer and P. L. B. Oxley. (*Chartered Mech. Eng.*, 1958, **5**, 419–420). Cutting tests on mild steel were filmed and the general shape of the plastic zone was found. A method of approximate analysis was developed agreeing well with the measurements under these particular conditions.

On the Economics of the Basic Turning Operation. R. C. Brewer. (*Trans. A.S.M.E.*, 1958, **80**, Oct., 1479–1485, discussion 1485–1489). Calculations are presented for the effects of savings from increased cutting speed set off against increased tool changing and grinding. An optimum degree of wear for minimum cost is shown. Other factors are mentioned and log-log paper plotting is recommended for feed-speed charts and nomogram construction is mentioned. (16 refs.). Other analyses are noted in discussion.

Metallurgical Factors and Machinability. J. Lomas. (*Machinery Lloyd*, 1948, **30**, Oct. 25, 82–84). [In English and Spanish]. A general discussion with some account of the effects of alloying elements in steel.

The Effect of a Lead Additive on the Machinability of Alloy Steels. N. Zlatin and J. V. Gould. (*A.S.M.E. reprint*, 58–SA–53, 1958, pp. 6). Turning tests with carbide tools are reported on two medium-carbon steels at different hardness levels. AISI 4147H and 4340H were used, normalized and quenched and tempered to R_C 26, 33 and 40–41 hardness levels. Tool life was increased with steels of R_C 30 or less, but the effect of the lead declined at higher levels and at some point between R_C 35–40 became detrimental. However, better surface finish and a reduction of power required of 15–25% was obtained in presence of Pb at all hardness levels.

Machining and Grinding Ni-Resist and Ductile Ni-Resist (Austenitic Iron Types). (*International Nickel Co. Inc. Publication*, pp. 21). Compositions and properties are tabulated and details of suitable tool materials and design, cutting fluids and speeds for most forming operations are given.

Controlled Contact Cutting Tools. B. T. Chao and K. J. Trigger. (*A.S.M.E. preprint*, 58–SA–42, 1958, pp. 9). Power consumption can be reduced, tool life increased, cutting fluids more effectively utilized and better surface finish obtained by control of time of tool-chip contact. The theory is discussed in terms of basic variables and artificially restricted contact tools appear to offer great possibilities for understanding the nature of machining processes.

Modern Cutting Tools Save Costs at High and Low Speeds. H. J. Siekmann. (*Iron Age*, 1958, **182**, Sept. 18, 95–97). Results are presented which show that cemented oxide machine tools often yield maximum economies at speeds below 1000 f.p.m.—A. G.

Cemented Carbide Tools Their Application for Increased Productivity in Heavy and General Engineering. D. C. Rogers. (*J. Inst. Prodn. Eng.*, 1958, **37**, Dec., 754–769). Examples are analysed.

Turning Alloy Steels with Ceramic and Carbide Tools. (*PERA Bull.*, 1958, **11**, Nov., 351–353). A report on trials with 11 types of tip is summarized.

Sinter Alumina for Cutting Tools. F. Singer and S. S. Singer. (*Refract. J.*, 1958, **34**, Oct., 456–462). Properties are given and compared with those of other materials. Design and performance are discussed and uses are indicated.

Limitations of High-Speed Milling Techniques. A. O. Schmidt. (*Eng. Dig.*, 1958, **19**, Oct., 432–434). A curve produced by Salomon in 1931 apparently showing a fall of chip-tool interface temperature at high machining speeds is shown to be due to failure of the thermocouples at the melting-point of one of their components. Tests on high-speed milling show that the temperature continues to rise and that tool wear becomes very great. Work on high strength materials is discussed. Analogies are drawn from gun barrel wear and from projectile impact.

Design and Performance of Two Milling Force Dynamometers. F. Koenigsberger, K. D. Marwaha and A. J. P. Sabberwal. (*J. Inst. Prodn. Eng.*, 1958, **37**, Dec., 727–742). Use is made of the occurrence of strain nodes in a loaded circular ring to separate strain measurements under vertical and horizontal loads. Octagonal rings are used in practice.

Reduce Residual Stress in Ground Parts by Correct Wheel Selection. J. A. Mueller. (*Metalw. Prod.*, 1958, **102**, Nov. 28, 2085–2087). Studies on residual stress production are reported and it is shown that this must be balanced against grinding efficiency, defined as amount of metal removed per unit of abrasive.

Stress Effects of Abrasive Tumbling. H. R. Letner. (*A.S.M. preprint* 104, 1958, pp. 17). Residual stresses induced in stress-free steel surfaces were found to be uniformly compressive in all directions and decreased from a maximum at the surface to zero at a few thous. depth. The particle size of the abrasive and hardness of steel were important. Stresses in ground samples were found to be replaced by typical tumbling stresses.—E. E. W.

Abrasive Cutting. Hölig. (*Wire*, 1958, June, 28–31). The technique of abrasive cutting, as an alternative to sawing or burning off, is explained and followed by a description of a number of machine tools of German and Swiss make.—J. G. W.

The Application of Spark Erosion Machining. A. J. Lawrance. (*J. Inst. Prod. Eng.*, 1958, **37**, Nov., 694–709). A very full account with several examples described and illustrated is given.

CLEANING AND PICKLING

Alkaline Electrolytic Descaling of Ferrous Metals and Alloys. (*Wire Wire Prod.*, 1958, **33**, May, 533, 586). Described is the AEDS patented process for descaling, using mains frequency A.C. The principal claims concern thoroughness of removal of scale and speed of action.—J. G. W.

The Progress of Mechanical Descaling in England. H. F. Sanderson. (*Wire Wire Prod.*, 1958, **33**, Oct., 1189–1191, 1278–1280). Satisfactory replacement of pickling by mechanical descaling is reported for steel rods up to 1·0%C. The features which have brought about the success are described in detail, and include a finishing temperature in the rod mill of 1560° F, use of a proprietary brand of soap in conjunction with pressurizing of lubricant in a special tube preceding the die, and drawing speeds somewhat lower than in use with pickled rod. Cost figures are quoted to prove that the process is no more costly than pickling.—J. G. W.

The Development and Practical Application of Shot-Blasting in Shipyards. (*Shipbuilder*, 1958, **65**, Oct., 579–581).

New Developments in 'In Situ' Cleaning. P. B. Wharton. (*Corros. Techn.*, 1958, **5**, Oct., 319). An account is given of a new grit-blasting abrasive, which is stated to be cheap, expendable and silica-free. This latter property may give new impetus to grit blasting which has been hampered by the prohibition of the use of silica-containing abrasives.—A. G.

Preparation of Steel Surfaces for Repainting. J. Hurst. (*Corros. Techn.*, 1958, **5**, Oct., 313–315, 342). Repainting at fairly regular intervals with a gradual build up of paint thickness is recommended. Suitable methods of cleaning paint work and rusted or contaminated surfaces are proposed.—A. G.

PROTECTIVE COATINGS

Protective Coatings Limit Corrosion. R. V. Jelinek. (*Chem. Eng.*, 1958, 65, Oct. 20, 163–168). A review of pretreatment, methods of application of metallic and other coatings, and factors in selection for chemical purposes is given. (30 refs.).

Design of a Plating Line. J. B. Mohler. (*Met. Fin.*, 1958, **56**, July, 65). Notes on plating rack design and tank requirements.

A Guide to Materials Standards and Specifications. 6. Finishes and Coatings. S. P. Kaidanovsky. (*Mat. Design Eng.*, 1958, **48**, Aug., 101–103).

Plating in the Production Line. D. J. Fishlock. (*Metalw. Prod.*, 1958, **102**, Dec. 12, 2175–2178). The use of automatic plating machines in a production line is described. Fumes and drainage are controlled so that they do not need to be isolated or to be mounted on chemically resistant foundations. Unskilled labour only is required. Notes on inspection, control and costs are added.

Pores and Pitting of Plated Deposits. J. M. Odekerken. (*Met. Fin.*, 1958, **56**, Oct., 64–66). Consequences, causes and investigation are outlined. Defects in pretreatment and suspended material, impurities and operating faults in the plating solution are considered.

Recovery or Disposal of Plating Wastes? R. J. Keating. (*Met. Fin.*, 1958, **56**, Sept., 46–48). Factors in the choice of exchange or precipitation methods are set out.

Water: Its Use in the Plating Shop. L. F. Spencer. (*Met. Fin.*, 1958, **56**, July, 44–51). A review of common impurities and their effects and of methods of conditioning and demineralizing. (47 references).

New Technique Rids Plated Steel of Hydrogen Embrittlement. H. H. Johnson, E. J. Schneider and A. R. Troiano. (*Iron Age*, 1958, **182**, July 31, 47–50). A thin layer of Cd is electro-deposited and baked, when it becomes impermeable to hydrogen. A second Cd layer of any thickness can now be deposited without any embrittling effect.—A. G.

Chromium Plating Baths Containing Sodium Fluorosilicate. IV: Microscopical Observation of Surfaces of Thick Deposits. T. Hayashi and S. Takagi. (*Rep. Gov. Ind. Res. Inst. Nagoya*, 1958, **7**, Oct., 763–770). Bath compositions and temperatures and current densities are given with numerous optical and electron micrographs of the surfaces produced. Crackless deposits can be obtained.

The Use of Hard Chrome Plating in Engineering. C. Wharrad. (*Inspection Eng.*, 1958, **22**, July-Aug., 74–79). An elementary account of the process and some of its difficulties is given and its use on gauges, in shaft hardening, on drawing dies and rolls and mandrels is briefly described.

Roller Burnishing of Heavy-Duty Parts Preparatory to Hard Chromium Plating. G. P. Kotlyakevskii. (*Metallov. Obra. Met.*, 1958, (7), 52–53). Three steels were tested using a standard burnishing process. Each was examined unplated without burnishing, machined before plating and a Cr layer 0·1 mm thick applied, and machined, burnished and plated. Tests were made with 10^7 reversals and the fatigue resistance was found to decrease with plating and to increase with burnishing. Full scale tests on pump shafts revealed the same effects.

Protective Coatings on High-Temperature Strength Alloys. V. A. Parfenov. (*Metallov. Obra. Met.*, 1958, (6), 33–37). Cr and enamel deposits for turbine blade alloys for protection against V_2O_5 and Na compounds were tested in fatigue.

Chromium Plating on Sprayed Metal. R. De Buyer. (*Met. Ind.*, 1958, **93**, Oct. 31, 373–374). A method of building up worn parts is described.

Electroplating and Electrorefining of Metals from the Sulphate Bath. T. L. Rama Char. (*Electropl. Met. Fin.*, 1958, **11**, Oct., 343–346). Plating of Ni, Cd, Zn, In, Pb and other metals is reviewed and some experimental work is described. (34 refs.).

Electroless Nickel. "Recorder." (*Met. Ind.*, 1958, **93**, July 18, 53–54). The development of the process and its operation are outlined.

Properties of Chemical Nickel and Cobalt Plating. J. L. Fiedler. (*Mét. Corr. Ind.*, 1958, **33**, June, 270–292). After outlining the chemical reactions involved, various practical processes are described. The properties of the deposits are discussed and resistance to attack by different media is summarized in tabular form. Finally examples of the application of chemical plating are given.

A New Black Nickel Plating Process. (*Met. Fin. J.*, 1958, **4**, Nov., 436–437). A new patented process from International Nickel is described. Effects of composition and operating conditions and the adhesion and ductility of the coatings are given. For outdoor use a lacquer coat is recommended.

Cathodic Electrodeposition Methods for Cobalt. D. Salyer and T. R. Sweet. (*Anal. Chem.*, 1958, **30**, Oct., 1632–1635). Tracer studies are described showing that Co always remains in the solution.

5th International Conference on Hot-Dip Galvanizing. (*Met. Fin. J.*, 1958, **4**, Sept., 333–358). Abstracts of papers and discussion are given. **Works Visits.** (359–364). Brief accounts of Johan Vis & Co. N.V., N.V. Plaatwerkereij en Verzinkerij v/h P. Bammens & ZN, S.A. des Usines à Tubes de la Meuse, Verzinkerij G. Clements & ZN, Travail Méchanique de la Tôle S.A., Phenix Works S.A., Cockerill-Ougree, (Seraing and Sambre. Escaut Divisions) and Metaalbuizenfabriek MIJ "Excelsior".

Contribution to the Question of Current Distribution in Concentrated Electrolyte Solutions. P. Csokán. (*Metalloberfläche*, 1957, **11**, Sept., 285–288; Oct., 316–320). In order to investigate the current distribution in concentrated electrolytes, a steel disc was suspended between the electrodes, and the patterns formed investigated. Two electrolytes were examined, namely $Cu(CN)_2$ and CrO_3. Photographs of the patterns produced are given, and the results obtained are given in tabular form. The results are discussed in the light of current theories. (7 ref.).

Ascertaining the Adhesion of Metallic Coatings on Wire. E. A. Franke. (*Wire Prod.*, 1958, **7**, Feb., 5–9). Brief reference is made to the wrapping test, traditionally used for qualitative assessment of coating adhesion to wire, and its limitations. There follows a description of quantitative tests, namely stripping, tension, and compression.

Electroplating of Screws and Other Small Parts, III, IV. W. Peters. (*Wire*, 1958, Feb., 19–24; Apr., 28–34). Measurement of thickness of deposits, quality control and costing are discussed. The latter is illustrated by numerous examples.—J. G. W.

Safety Measures in Electroplating. M. Vukadinovic. (*Zaštita Mat.*, 1955, **3**, Apr., 138–142).

The Production of Salts for Chromium Plating. N. Manger. (*Zaštita Mat.*, 1955, **3**, Aug., 263–266, 276). The production of chromic acid and chromates is shown schematically with tests for purity.

The Process of Hard Chrome Plating. L. Ilic. (*Zaštita Mat.*, 1955, **3**, Aug., 267–270). Defects are reviewed and the best conditions for plating indicated.

Workshop Recipes and Control of the Bath for Hard Chromium Plating. S. Vučkovic. (*Zaštita Mat.*, 1955, **3**, Aug., 277–280). Limits for satisfactory plating bath compositions are indicated and control methods given.

Structures of Iron and Chromium Deposited on Copper Single Crystals. A. Goswami. (*Trans. Farad. Soc.*, 1958, **54**, June, 821–825). An electron-diffraction study is reported, epitaxis is discussed.

The Use of Hard Chromium Plating and Applications in Galvanoplasty and Printing. T. Topalovic. (*Zaštita Mat.*, 1955, **3**, Aug., 273–276). Application to printing blocks is discussed.

Chromallized Steel. R. P. Seelig. (*S.A.E.J.*, 1958, **66**, May, 42–44). A chromium diffusion process giving a corrosion-resisting ductile coating is described. The products are superior in fabrication and weldability to the 18–8 steels. Heat, wear, and corrosion resistance are discussed and something is said on costs.

Bright Nickel Plating–5–Brightening Agents. D. J. Fishlock. (*Prod. Fin.*, 1958, **11**, June, 65–75). Proprietary agents are tabulated and various bath compositions are indicated. Mechanisms of bright plating are then discussed. (20 ref.).

Studies on Electroless Nickel Plating. C. H. de Minjer and A. Brenner. (*Plating*, 1957, **44**, Dec., 1297–1305). Effects of pH, nature of buffer and complexing acid on rate of deposition and comparative outdoor exposure tests are reported. Glycollic and lactic acids gave the highest rates, the curves with concentration showing a maximum. The electroless plate with 9% P gave better protection than electrolytic Ni or Ni–P alloy.

Continuous Galvanising Under Electric Control. (*Elect. Times*, 1958, **134**, July 17, 83–86). An account of the electrical system at the Ebbw Vale plant.

Fully Automatic Hot Galvanizing Plant. J. Kohlgrüber. (*Wire*, 1958, Feb., 18; *Draht*, 1957, **8**, Aug., 335–336). A hot galvanizing plant for pipe fittings, marketed by Ofenbau GmbH, Berg & Co., Köln-Kalk, Germany, is described and illustrated. The plant comprizes pickling, rinsing, fluxing, drying, galvanizing, and water quenching and accepts only sand blasted parts which are conveyed on hooks, carried by endless feed chains within each section of the plant. By altering the sequencing mechanism the sojourn of a part in any section of the plant can be altered.—J. G. W.

Galvanizing by the Sendzimer Process. K. Oganowski. (*First Nat. Congress Iron and Steel Industry* [*Mexico*], 1955, 291–292).

Characteristics and Possibilities of the "Preflex" Process. D. Stanojevic. (*Zaštita Mat.*, 1955, **3**, Aug., 271–272). A bright zinc electroplating process is noted and its possible uses reviewed.

Industrial Applications of Coated Steel Sheet. F. H. Smith. (*Acier-Stahl-Steel*, 1957, **22**, Dec., 481–488). The author discusses the joining, protection, storage and uses of galvanized or Ni–Zn coated steel sheet. E. Marks. (489–490). A discussion of the characteristics and uses of various types of coated steel sheet.—R. P.

"Prefluxing" in Hot-Dip Galvanising. H. Bablik and M. Behlolavy. (*Metalloberfläche*, 1957, **11**, Oct., 313–315). The importance of fluxing in preventing the formation of hard zinc is emphasized, examples from practice being given.—L. D. H.

The Use of Fluxes in Galvanizing. A. Herz. (*Met. Constr. Mécan.*, 1957, **89**, May, 463–464; Nov., 955–957). The purpose served by the flux and its necessary properties, (liquid at working temperature, solvent for oxides, protecting against oxidation and capable of displacement from the surface by Zn) are noted and compositions of chloride fluxes and their methods of use are briefly indicated. Hachmeister's diagram of the $ZnCl_2$–NH_4Cl system is referred to and the use of binary, ternary and eutectic salts is described. Loss of Zn and the use of cover fluxes are briefly discussed.

Consideration of the Formation of Drosses in Galvanising Baths. A. Herz. (*Mét. Constr. Mécan.*, 1958, **90**, Mar., 197–199). The properties of mattes found in galvanizing baths are considered. Factors affecting the formation of mattes are discussed; these include temperature, iron and fluxing salts.

The Steel Industry and the Use of Modern Methods in the Production of Steel and Tinplate. R. Vega. (*Second National Congress of the Iron and Steel Industry* [*Mexico*], 1957, 189–205). An account of the manufacture of tinplate is given.

The Use of Electronics in Tinplate Manufacture. (*Tin*, 1958, Apr., 73–74). A brief review.

The Basis of Acid Copper Plating and the Cupatier Process. W. Strauss and E. Roth. (*Metalloberfläche*, 1957, **11**, Sept., 281–285). The electrochemical process is considered and the development of the Cupatier bath bright plating process is described.

Stainless Steel Plated Sheet. (*Met. Constr. Mécan.*, 1957, **89**, Nov., 935–937). Stainless steel sheet is difficult to work and therefore plated sheet is used. It offers the advantage that the thickness, base metal and grade of plating can be varied.—R. P.

Metal Spraying—A Cold Metallurgical Treatment. L. Ilic. (*Zaštita Mat.*, 1955, **3**, Sept., 305–309). Both anticorrosive and machine part repair procedures are reviewed.

Experiments with the Spray Gun for Powder Metallization. L. Ilic and H. Lajšic. (*Zaštita Mat.*, 1955, **3**, Sept., 316–317). Besides Zn and Al, Fe, glass and enamel spraying is briefly considered.

Experiences with Metal Spraying in Yugoslavia and Abroad. J. Gruden. (*Zaštita Mat.*, 1955, **3**, Sept., 310–314). Protection of large hydroelectric constructions *in situ* is described.

The Development of Metal Spraying Processes with Special Reference to Conditions in Yugoslavia. F. Podbrežnik. (*Zaštita Mat.*, 1955, **3**, Sept., 299–304). A review with an extensive bibliography.

Metallization as Protection against Corrosion. J. Gruden. (*Zaštita Mat.*, 1955, **3**, Oct., 339–342). Zinc spraying is particularly considered.

Influence of Oxides on the Physical and Mechanical Properties of Steel Metallised Layers. L. V. Krasnichenko and M. N. Schirzhetskii. (*Fiz. Met. Metalloved.*, 1957, **5**, (1), 137–141). During the process of electro-metallization, at the instant of fusion by the electric current, the metal takes up air, disintegrates and settles on the surface.

The physical and mechanical properties depend to a large extent on the composition, the quantity and the form of stratification

of the oxides. Experimental results show that the metallized layer after certain thermal treatments, can be used as independent material for machines, owing to its mechanical and antifriction properties. The shaft of a lathe, on which the bronze bearings were replaced by metallized ones, has been working normally for the last two years.—L. B.

Further Development of Metal Spraying Technique (III). H. Reininger. (*Metalloberfläche*, 1957, **11**, (Oct., 329–333). This section deals with technical aids to metal spraying, pre-treatment of the surface, structure and properties, subsequent treatment of the surface, hard soldering and welding by spray techniques, surface protection against corrosion and scaling, flame spraying, repairing and testing.—L. D. B.

Flame Spraying Non-Metallic Protective Layers on Metal Surfaces. H. Reininger. (*Metalloberfläche*, 1957, **11**, Dec., 393–400). This is a general survey of the literature dealing with preliminary treatment, spraying equipment, the manufacture of material for spraying, and the properties and applications of the coatings. (72 ref.).

The Browning of Steel. M. Trpkovic. (*Zaštita Mat.*, 1955, **3**, May, 169–172). Seven methods are outlined.

Evaluating Rust Prevention Greases: American Experience. E. Ford. (*Corros. Techn.*, 1958, **5**, Oct., 332). Two tests have been investigated, one static in which a greased roller bearing is stored at high humidity and the other dynamic with a rotating roller bearing sprayed with water. At present neither test is able to do more than distinguish between good and bad greases, but development is continuing.—A. G.

Inside a Vitreous Enamelling Works. A. H. Symonds. (*Prod. Fin.*, 1958, **11**, Oct., 88–90). An illustrated account of the Vulcan Stove Co. works.

New Type of Continuous Electric Enamelling Furnace. (*Met. Fin. J.*, 1958, **4**, Oct., 398–399). An illustrated account of the furnace installed at Enfield. It has five zones with a maximum temperature of 880° C, five indicating and a 6-point recording pyrometers, suspended roof and conveyor chain.

Fusing Furnaces, Types, Operation and Maintenance. J. Bradbury. (*Inst. Vit. Enamel. Bull.*, 1958, **9**, Nov. 44–50). Illustrations and diagrams are given of batch and continuous furnaces and their operating characteristics, installation and maintenance are considered.

On the Adherence of Porcelain Enamel to Sheet Steel. J. Berk and J. de Jong. (*J. Amer. Ceram. Soc.*, 1958, **41**, Aug., 287–293). A study of interface reactions by means of microscopy, electron microscopy and light and X-ray spectrometry was made to decide between the various theories of adhesion and the effects of Co and Ni oxides. Various types of bonding are distinguished.

Porcelain Enamels and Ceramic Coatings. R. J. Fabian. (*Mat. Design Eng.*, 1958, **48**, July, 103–118). This is Manual No. 150. A glossary of terms is given and a general account of nature, properties and uses.

Glass-Protected Steel. (*Prod. Eng.*, 1958, **29**, Sept., C10; from *A.O. Smith Corp. Bulletin*). The advantages of glass-coated steel and the physical properties of the glasses used are enumerated.

Developments in Porcelain Enamel Coatings. (*Prod. Eng.*, 1958, **29**, Sept., C2–C3). Porcelain enamels are defined, and modern developments in the material, its finish and applications are described.

Developments in Steel Shot and its Applications to Vitreous Enamelling. D. W. S. Hurst and J. Bradshaw. (*Met. Fin. J.*, 1958, **4**, July, 276–280; *Inst. Vit. Enamel Bull.* 1958, **9**, Nov., 37–41). Advantages of steel over cast iron abrasives are noted and the application of the Wheelabrator and Steeletta to the pretreatment of metal for enamelling is discussed.

Wear and Tear of Enamelled Surfaces. J. W. G. Pedder. (*Met. Fin. J.*, 1958, **4**, July, 259–268). Scratch test apparatus and abrader tests are described. The shape and profiles of scratches and the mechanism of abrasion and stages of breakdown are discussed.

A Review of Zirconium Bath Enamels. W. A. Ross. (*Inst. Vit. Enamel. Bull.*, 1958, **9**, Oct., 27–35). With discussion.

Effect of Heat-Treatment on Properties of Enamel-Steel Composites. J. H. Healy and L. K. Breeze. (*J. Amer. Ceram. Soc.*, 1958, **41**, Oct. 381–386, discussion, 386–389). Tangential deflection was measured on glass-steel strips heat-treated below and in the transition zone of the glass. The change after heat-treatment was similar to change in flexure breaking stress, thermal shock resistance, resistance to fish scaling and spalling in acid environments after heat-treatment.

Ten Painting Reminders for Steel Plants. W. T. Yarhouse. (*Iron Steel Eng.*, 1958, **35**, Sept., 129–141). 10 Considerations covering the selection, preparation, application and conditions of use of paint in steel plants are discussed. An appendix deals with common finishing troubles and defects and their correction.

Lead Pigments in Corrosion-Resistant Paints. (*Corros. Techn.*, 1958, **5**, Nov., 353–354). An outline of the use of red lead, with linseed oil, as a priming paint for steel structural work is followed by a description of the application of calcium plumbate as a pigment.

Applying Paint to Galvanised Iron. (*Ind. Fin.*, 1958, **10**, Aug., 34–35). The Lithoform and Granodine 33 processes for phosphate coating are described.

Developments in Ships' Protective Coatings. F. Perkins. (*Corros. Techn.*, 1958, **5**, Aug., 247–249). Modern paints that fulfil the requirements of complete protection, i.e. they should have high electrical resistance and at the same time restrict contact between the metal and the electrolyte, are reviewed. The various types of paints and their vehicles available on the market are discussed with respect to complete protection.—T. G.

Plant for Pre-Painted Steel Strip. (*Machinery*, 1958, **93**, Nov. 5, 1061–1065). A plant installed at Walsall is described.

CLAD SHEET AND HARD-FACING

Materials Selector: Finishes and Coatings. (*Mat. Design Eng.*, 1958–59, *Reference Issue*, **48**, Mid-Oct., 258). Hard coatings are tabulated with properties.

Hard Facing Adds to Guide Life. (*Steel*, 1958, **142**, June 23, 96). Hard faced mild steel guides in rolling mills have been found to last 6–9 weeks in comparison to 2–3 weeks for normal guides. Maintenance is said to be reduced 300%.—A. G.

Coating Upgrades Low Cost Tools. (*Steel*, 1958, **143**, July 21, 118). Spark deposition is being employed to put WC surfaces on low-cost high-speed cutting tools. The resultant surface has shallow craters lined with hard electrode metal.—A. G.

Electrophoretic Deposition. (*Metalw. Prod.*, 1958, **102**, Oct. 31, 1919–1921). A process developed by the Vitro Corp. of America for depositing metallic or ceramic coatings is described. Structures are shown and various characteristics indicated.

Properties and Applications of Flame-Sprayed Refractory Coatings. L. Manuel. (*Inst. Vit. Enamel Bull.*, 1958, **9**, Nov., 51–54). A lecture reviewing recent work and giving the properties of Al_2O_3 and ZrO_2.

Uses Grow for Ceramic Coatings. F. D. Shaw. (*Iron Age*, 1958, **182**, Sept. 25, 94–95). New developments in ceramic coatings for use on metals at high temperatures are reviewed. Although the current emphasis is on this aspect, such coatings have many other valuable properties, notably corrosion resistance.—A. G.

Sprayed High-Melting-Point Metals. J. Cauchetier. (*Met. Ind.*, 1958, **93**, Oct. 31, 374–375). The adhesion of Mo to steel was examined and factors on which it depends and the structures produced were identified.

The Rostenit Process. (*Usine Nouv.*, 1958, **14**, Nov. 27, 99). A brief account of a facing process with corrosion-resisting metals for the repair and protection of metals subject to serious corroding conditions such as flues carrying smoke laden with SO_2.

An Introduction to Vacuum Metallising. M. A. Self and J. Scharnberg. (*Met. Fin.*, 1958, **56**, Aug., 54–57). Flow coating or dipping, spraying and baking are described and a comparison with Cr plate is made.

New Applications of Hard Facing with Tungsten Carbide. (*Prod. Fin.*, 1958, **11**, Oct., 91–92). Rock bit coating is described

Carbide Co-deposition. (*Metalw. Prod.*, 1958, **102**, Aug. 29, 1514). Deposition of hard carbide particles in a metal matrix can be carried out. The coatings are said to outlast hard chrome plating.

Tungsten Carbide Rollers are Tough. (*Steel*, 1958, **143**, Sept. 22, 86). Pelletizing machine rollers consisting of forged 1020 steel with a welded coating of 20/30 mesh tungsten carbide have superior wear resistance to hard faced rollers and are said to be cheaper to make.

Abrasion Resistant Hard Facing Boosts Oil Drilling Parts Life, Productivity. P. Richardson. (*Western Metalw.*, 1958, **16**, Aug., 40–41). Uses of Colmonoy (chromium boride in Ni alloy) are noted.

Bonding Iron to Aluminium by Casting-on. H. Kessler. (*Light Metals*, 1958, **21**, Nov., 355–356; from *Klepsig Fachberichte* 1957, (11), *Tech. Rep.*, G33/K29). A process is indicated in which an aluminized iron or other insert is heated to a temperature at which the coating becomes viscous and Al is poured upon it in a mould. It is shown that an oxide film is produced which prevents the formation of a good joint. To eliminate this, processes for removing the oxide film have now been developed, notably the use of eutectic Al–Si alloy, or the use of a bath of Al–Si–Zn alloy. Micrographs of both kinds of joint are shown.

On the Residual Stress Distribution of Aluminium-coated Steel Sheet. T. Saga and K. Satō. (*Nippon Kinzoku*, 1958, **22**, Feb., 70–73). From experiments with Al-coated, annealed mild steel sheets 0·2 mm thick, it is concluded that the residual stress pattern depends more on coating temperature than time, consists generally of compressive stresses in the coating and tensile stresses in the base, and the magnitude of the stresses increases with temperature and time of coating.

Swedes Make Modern Bearings. A. E. Olsson. (*Metal Progress*, 1958, **74**, Aug. 58, 91–93). The plant and method used for lining heavy-duty bearings with Babbitt are described. The bearing shells are first electrolytically cleaned in a salt bath in which the polarity is periodically reversed. After tinning, the bearing goes to a centrifugal casting machine where it receives a Babbitt coating of desired thickness. The bond is extremely good.—D. L. C. P.

POWDER METALLURGY

Electrodeposition of Metal Powders. G. Gabrielson. (*Ind. Chem.*, 1958, **34**, Oct., 529–532). General principles are outlined.

Metallurgy of Powder Metals. (*Tecn. Indust.*, 1958, **37**, Jan.-Feb., 65–70). [In Spanish]. In this brief review an account is given of the technical details of powder metallurgy, with reference to iron and bronze products such as friction plates. An account of cermet materials is also given.—P. S.

On Sintering Stainless Steel Powder. M. Sugiyama and H. Suzuki. (*Nippon Kinzoku*, 1958, **22**, Feb., 67–70). Account is given of investigations in which the variables of the process, namely sintering pressure, temperature, and time, were studied. Their effects on the physical properties of the compacts are shown in graphs.—J. G. W.

Who Uses Sinterings. (*Prec. Met. Mold.*, 1958, **16**, Nov., 24–27). Parts are shown as made by a number of companies.

Design Properties of Sinterings. II. Ferrous Alloys. (*Prec. Met. Mold.*, 1958, **16**, Nov., 30–33). Data from 17 firms are tabulated giving compositions and mechanical properties.

New Thermo-chemical Techniques. II. Powder-Metallurgical Applications. P. Galmiche. (*Met. Treatment*, 1958, **25**, Nov., 449–454). Uses of Cr diffusion with sintered iron part production are described.

Realistic Tolerances for Sinterings. R. Burgess. (*Prec. Met. Mold.*, 1958, **16**, Oct., 52–53). A table of reasonable values is given.

Self-Lubricating Fe–Cu Bearing. I. Mechanism of Pore Formation. T. Watanabe. (*Rep. Gov. Ind. Res. Inst. Nagoya*, 1958, **7**, Oct., 743–752). Above the $\alpha \rightarrow \gamma$ transformation point (910° C) inherent voids grow slightly because of accompanying shrinkage. Above the m.p. of Cu the copper grains melt and spread giving "copper-off" cavities with shapes similar to those of the original grains and slightly larger on account of corrosive action on the iron. Following alloy formation the voids grow still further. Densification sets in after long heating.

Sintering in Operation at the Queiroz Junior Plant. J. J. Carneiro de Mendonça. (*Bol. A.B.M.*, 1958, **14**, Jan., 31–40). [In Portuguese]. A full description of the continuous rotating table system of sintering supplied by Lurgi-Chemie is supplied. Operational data, including costs, are given.—P. S.

Boost Powder Metal Part Size. R. H. Weichsel. (*Iron Age*, 1958, **182**, Oct. 2, 80–81). Large powder metal parts may be made by bonding several pieces together with silver solder. It is claimed that joints are permanent and have tensile strengths equal to those of the matrix material.—A. G.

A Method of Assessing the Die-Filling Characteristics of Powders. J. Oakley. (*J. Inst. Met.*, 1958, **87**, Sept., 26–28). Limitations of methods of flow testing and apparent density measurement of metal powders are discussed and a method of determining die-filling characteristics is given with direct application to tool design.

How to Finish Sinterings in Barrel. (*Prec. Met. Mold.*, 1958, **16**, Nov., 45). Parts are shown and processing data tabulated.

Electroplating Improves Properties of Iron Powder Articles. (*Ind. Fin.*, 1958, **10**, Sept., 50, 52, 54). Work at Battelle is described. Plating methods are outlined and bath compositions are given. Advantages are noted.

FERRITES, CERMETS, AND CARBIDES

Ferrites. E. Albers-Schoenberg. (*J. Am. Ceram. Soc.*, 1958, **41**, Nov. part II, 484–489). Types of ferrites and their uses are indicated.

Microstructure and Properties of Ferrites. S. L. Blum. (*J. Am. Ceram. Soc.*, 1958, **41**, Nov. part II, 489–493). The influence of structure on magnetic properties is discussed.

Magnetization Processes in a Polycrystalline Manganese Zinc Ferrite. L. F. Bates, H. Clow, D. J. Craik and P. M. Griffiths. (*Proc. Phys. Soc.*, 1958, **72**, Aug. 1, 224–232).

Data on Ferrite Core Materials. A. C. Hudson and E. J. Stevens. (*Electronic Eng.*, 1958, **30**, Dec., 718–719).

Investigation of the Sintering of the Metal-Ceramic Alloys on a Base of the Fe–Ni–Al System. A. B. Al'tman. (*Fiz. Met.*, 1958, **6**, (3), 456–465). The sintering process is of a complex chemical and physical nature proceeding successively or simultaneously and attains its greatest development at a certain temperature. Its influence is then predominant on the structure and properties. Three alloys were prepared by powder metallurgy.

% Al	Ni	Co	Cu	Ti	Fe
13·0	25·0	—	4·0	—	58·0
10·0	17·0	12·5	6·0	—	54·5
8·5	14·0	24·0	3·0	1·0	49·5

Three stages of the process should be noted; first, the reduction of oxides, increase in the area of metallic contact between the compacted parts, recovery and recrystallization of the parts. In the second, reciprocal solution of the parts, dispersion hardening of the solid solution obtained, growth of the specimens. The third phase, homogenization and dispersion of the hardness of the solid solution, growth of grains and shrinkage of the specimens. It has also been shown that it is not necessary to connect the large shrinkage of the Fe–Ni–Al alloys with the formation of the liquid phase during sintering.—L. H.

The Fabrication and Properties of Chromium–Alumina and Molybdenum–Chromium–Alumina Cermets. J. B. Huffadine, L. Longland and N. C. Moore. (*Powder Met.*, 1958, (1–2), 235–252).

A Guide to Ferromagnetic Ceramics. G. Economos, (*Mat. Design Eng.*, 1958, **48**, Sept., 96–101; Oct. 109–114).

Sintered Products and Cermets. J. F. Roberts. (*Ceramics*, 1958, **9**, Sept., 6–8, 10). A general account, mainly of alumina, but including notes on ZnO_2 and MgO. Physical properties are considered and uses noted.

Evaluation of Tensile, Compressive, Torsional, Transverse and Impact Tests and Correlation of Results for Brittle Cermets. M. J. Kerper, L. E. Mong, M. B. Stiefel and S. F. Holley. (*J. Res. N.B.S.*, 1958, **61**, Sept., 149–169). Specimens and apparatus for tests on brittle material are developed. Elastic properties and tensile strengths were computed from the various determinations. Impact values did not correlate with other mechanical properties.

The Fabrication and Properties of Uranium Oxide–Iron Cermets. W. J. Wright, R. B. Gibbon and J. Williams. (*Powder Met.*, 1958, (1–2), 253–272). The materials are extruded as reactor fuel elements.

PROPERTIES AND TESTS

Bibliography of Model and Pilot-Plant Applications in Ferrous Metallurgy 1945–56. W. O. Philbrook. (*U.S. Bur. Mines, Inf. Circ.* 7851, 1958, pp. 13).

7 Closer Looks at Metal Properties. E. Loria. (*Prod. Eng.*, 1958, **29**, Oct. 27, 48–49). Points to note to obtain more information from test results are suggested. Rate of strain in yield strength data, transverse properties of forged metals, compressive strength, which may differ from tensile, fatigue strength, tear strength, bi-axial stresses and surface defects.

Simulated Service Life Testing. T. Haas. (*Engineer*, 1958, **206**, Nov. 14, 754–756; Nov. 21, 794–797) Laboratory and service fatigue values do not always agree so that full-scale part testing has become more frequent The loading met with in service is also simulated. Examples from the aircraft field are given. The programme loading machine is described and illustrated and its applications indicated.

Equivalent Steel Specifications. J. S. Tritton. (*Rail Steel Topics*, 1958, **4**, Autumn, 5–8). A chart of the properties of 6 British and Continental mild and high-tensile steels is given and the topic of specification equivalence is discussed.

ASTM and the Steel Industry: Two Case Histories. N. P. Veeder. (*A.S.T.M. Bull.*, 1958, July, 57–58). Cases illustrating the need for standard specifications and for their revision as manufacturing processes change are quoted.

Alloy Steel Wire. (*A.I.S.I. Steel Prod. Man.*, 1958, Aug. pp. 46). Tables of gauges are added.

Surface Finish. K. G. Lewis. (*Met. Treatment*, 1958, **25**, Sept., 377–384). The effects of strain-hardenability, microstructure, grain size, alloying elements and the use of free-cutting materials; the Beilby layer and "smear metal" and its removal, and the effect of cold work on surface finish are discussed, with a note on grinding. (26 refs.).

On Asperity Distributions of Metallic Surfaces. F. F. Ling. (*J. Appl. Phys.*, 1958, **29**, Aug., 1168–1174). The model of two surfaces with asperities in the form of right circular cones is evaluated for steel, brass and Al. Measurements support the theory.

Surface Finish. Metallurgical and Mechanical Aspects. K. G. Lewis. (*Met. Treatment*, 1958, **25**, Aug., 335–342.) Definitions of roughness and surface finish are given and machining conditions and the formation of the built-up edge and chip form are discussed. Effects of cutting speed, feed and depth of cut, rake angle and tool form and mechanical and metallographic factors are then considered.

Metals Testing at High and Low Temperatures. (*A.S.T.M. Bull.*, 1958, July, 50–51). A table of mechanical and physical testing facilities in the U.S.

Elastic Variation Method for Studying the Kinetics of the Variation of Properties of Metals and Alloys During Heating. M. G. Lozinskii and A. E. Fedorovskii. (*Izvest. Akad. Nauk. Otdel. Tekh.*, 1958, (6), 19–29). The use of dynamic method of measuring the modulus of elasticity and internal friction of metals and alloys is reviewed. A device developed at the Institute of Engineering Studies of the U.S.S.R. Academy of Sciences for studying the relationship between temperature and these properties is described. The authors discuss the results of experiments to examine internal friction in the tempering of low-alloy structural steels and also internal friction in iron caused by the presence of dissolved nitrogen.—R. S.

Effect of the Annealing Temperature on the Mechanical Properties of Nodular Graphite Cast Iron and on the Diffusion of Phosphorus. S. G. Guterman and G. A. Pisarenko. (*Fiz. Met.*, 1958, **6**, (2), 311–314). The test material was a cast iron (deoxidized in the ladle with 0·5% Mg) of composition: 3·2%C; 2·63%Si; 0·58%Mn; 0·13%P; 0·01%S. The specimens were annealed at temperatures between 800 and 1000° at 50° interval. Experimental findings have shown that up to 950° the elastic properties increase considerably, most of all the breaking strength, but that no increase can be noticed beyond this temperature. Why there should be a deterioration of these qualities after annealing was investigated with radioactive ^{32}P. Under actual conditions of casting, when crystallization occurs at considerably higher rates of chilling, and owing to the partial suppression of diffusion, two causes for the non-uniform structure may make their appearance depending upon whether the eutectic is formed with a phosphorus concentration below equilibrium level or with a concentration sufficient for crystallization. In the first case, it is possible to inhibit the formation of the phosphide eutectic but not in the second.—L. H.

On the Distribution of Plastic Deformation in Polycrystalline Metals. P. O. Pashkov and V. A. Bratukhina. (*Fiz. Met.*, 1958, **6**, (1), 128–134). The phenomenon of periodicity in the distribution of plastic deformation in a deformed polycrystal is studied in a number of structural steels. This phenomenon is a natural result of the over-all heterogeneity of deformation of the grains of a polycrystalline metal. It appears that deformation in a body consists of regions of slight deformation and zones in which deformation is marked. Such deformation zones are as much as twice the order of magnitude of the grains forming the polycrystal. This type of heterogeneity of the deformed state is associated with corrosion.

The Occurrence of Stacking Faults in Metallic Systems. J. Spreadborough. (*Phil. Mag.*, 1958, **3**, Oct., 1167–1173). A possible qualitative explanation is given in terms of the partly occupied hybrid orbitals with directional properties, and the results are applied to the ε-phase in Fe–Mn and to non-ferrous systems.

Observations of Dislocations in Iron Whiskers. R. V. Coleman. (*J. Appl. Phys.*, 1958, **29**, Oct., 1487–1492). Etching produces pits at dislocations on {100} faces of iron. These develop only after deformation and increase with degree of deformation but not with etching time. Annealing at 850° C for 6–100 h and then etching produced alignment of the pits. Patterns are shown and discussed.

The Propagation of Cracks and the Energy of Elastic Deformation. H. F. Bueckner. (*Trans. A.S.M.E.*, 1958, **80**, Aug., 1225–1230; 1957, preprint 57–A–189, pp. 16). The Irwin-Orowan treatment is extended to a general analysis of energy supply. The energy for crack extension is shown to come from two sources, the work of externally impressed forces and the change of strain energy and the sum is equal to the difference between the stress fields before and after crack extension. Other conclusions are arrived at also, using Clapeyron's theorem and Betti's reciprocal theorem and a three-dimensional viewpoint.

Continuous Distributions of Dislocations. V. Twisting under Conditions of Single Glide. B. A. Bilby and L. R. T. Gardner. (*Proc. Roy. Soc.*, 1958, **247**, Sept. 9, 92–108).

Spin of ^{57}Fe. G. W. Ludwig, H. H. Woodbury and R. O. Carlson. (*Phys. Rev. Letters*, 1958, **1**, Oct. 15, 295–296).

The Case Against the Tension Test. J. B. Caine. (*Foundry*, 1958, **86**, Sept., 78–85). Various factors in tensile testing are discussed to show that tensile tests are unsuitable as a means of evaluating service properties.

Evaluation of Stress-Strain Recorders. (*N.B.S. Tech. Bull.*, 1958, **42**, Sept., 172–174). Methods of calibration are described.

The Energy Stored in Deformed Metals. L. M. Clarebrough and M. E. Hargreaves. (*J. Australian Inst. Met.*, 1958, **3**, May, 31–43). 'Crystal defects' and their effect on metal properties are briefly discussed. Measurements of stored energy in coppers of varying purity and in nickel are reported which give information about the type, concentration and arrangement of these defects.

The Failure of Metals Under Load. H. Muir. (*J. Australian Inst. Met.*, 1958, **3**, May, 44–60). Fundamental Australian research projects on yielding, brittle fracture, creep, stress-corrosion and fatigue are outlined. Dislocation theory enables the different modes of failure to be integrated. The fundamental approach has resulted in a number of successes including the production of ductile chromium.—A. G.

Symposium on Large Fatigue Testing Machines and their Results. (*ASTM spec. Tech. Publ. No.* 216, 1958, pp. 151). **Introduction.** J. M. Lessells. **A Unique Machine for Large Scale Fatigue Testing.** H. V. Cordiano. (3–17, discussion 18–20). A machine on the principle of the dynamic vibration absorber is described. A rotating couple generated by revolution of 2 sets of eccentric discs is used and the weighted test specimen is the absorber. **Torsional Fatigue Testing of Axle Shafts.** E. J. Eckert. (21–33, discussion 34–36). A machine using hydraulic non-rotary, constant-load is described and effects of surface condition and hardness were examined, also stringer content, hardness profile, chemical composition and shot peening intensity. SAE 86B45H and 4150 steels were tested at a Rockwell hardness of C45 or over. Maximum strength was found at C50–55, the fatigue strength was found to be somewhat below that found for smaller specimens by other workers. **Fatigue Testing of Airframe Structural Components.** H. W. Foster. (37–53, discussion, 54–58). Wing joints and landing gear were tested. SAE 4340 steel components were included. **Fatigue Performance of Marine Shafting—Laboratory and Service Tests.** T. W. Bunyan. (59–79, discussion 79–80). The arrangement of the machine is shown testing shafts from 5½–10 in. diameter. The effects of fillet radius were particularly examined and two distinct forms of cracking and crack propagation were found. Findings in service are reviewed and the slow rate of crack propagation in mild steel and the value of inspection are noted. **Fatigue Tests of Large Alloy Steel Shafts.** F. C. Eaton. (96–103, discussion 103–106). Tests on 9 in. diameter unnotched and 8½ in. notched shafts are being made. A rotating-beam type of machine with misaligned bearings was used, and for small specimens a rotating-cantilever machine. No discussion of an apparent size effect is offered at this stage. **Influence of Operating Experience and Full Scale Tests on Propulsion Shafting Design of U.S. Navy Ships.** R. Michel. (107–121, discussion 122–131). Causes of failures in service are discussed and various tests and design considerations are described. **Sudden Fracture of Machine Parts and Structure Elements.** G. V. Uzhik, M. J. Galperin and A. A. Zooykova. (132–141). The transition from fatigue failure to brittle fracture is considered and tests on notched sections are described. **Determination of Dynamic Loading in Full Size Fatigue Tests and Some Results.** S. V. Serensen and M. E. Garf. (142–151). Classification of fatigue machines is considered and bending test and torsion machines designed by the Ukraine Academy of Sciences are mentioned with test results on crankshafts.

The Fatigue Strength of Specimens Cut from Pre-Loaded Blanks. N. E. Frost. (*Metallurgia*, 1958, **57**, June, 279–282). Test results indicate that prior fatigue testing has no effect on the fatigue strength of Al alloy L.65. Static pre-loading in compression or torsion increases the fatigue strength of mild steel and decreases it for alloy L.65.—A. G.

A Machine for High Temperature Fatigue Testing of Gas Turbine Buckets. J. O. Anderson and C. F. Sanborn. (*Proc. Soc. Exper. Stress Anal.*, 1957, **15**, (2), 11–20). Air nozzle excitation of vibrations is used, heating is by oxy-acetylene torch. Typical results are quoted.

Fatigue Strength of Austenitic Steels Exposed to Corrosive Gases at High Temperatures. A. V. Ryabchenko and E. L. Kazimirovskaya. (*Metallov. Obrabotka Met.*, 1958, (3), 6–10). Fatigue limits for austenitic steels for gas turbine blades were measured in presence of SO_2 and moisture equivalent to gases from underground gasification (4·44% CO_2, 0·26% SO_2, 5·7% H_2O, 14·2% O_2, 75·4% N) and at higher SO_2 concentrations. CO_2 was shown to be without effect up to 650°. Scaling was also examined. Water vapour increases total corrosion but prevents local corrosion, the latter effect predominating so that the total effect is small.

Physics of Fatigue and Creep in Metals. T. Yokobori. (*Metal Physics*, 1957, **3**, July, 141–149). [In Japanese].

Formation of Fatigue Cracks. W. A. Wood. (*Phil. Mag.*, 1958, **3**, July, 692–699). A method of taper sectioning is used giving an optical magnification of × 20,000. Slip bands turning into cracks are revealed and the effect of amplitude in cyclic straining, the form of the S/N curve arising from superposition of two mechanisms. Fatigue cracking appears to be a consequence of to-and-fro slipping in slip bands.

Pulsating Pressure Fatigue Tests on Pressure Vessel Branch Connections. P. H. R. Lane. (*Brit. Weld. J.*, 1958, **5**, July, 327–332). Model vessels were examined (20 in. diameter × 1 in. thick) each with one branch welded in, one interpenetrating and one not penetrating the shell thickness. Fracture showed that the latter construction weld root areas were not sources of weakness.

Application of F. Stüssi's Fatigue Theory to the Results of Creep Tests. W. Stauffer and A. Keller. (*Arch. Eisenhütt.*, 1958, **29**, July, 411–414). The method is based on Stüssi's presentation of the creep curve, i.e. log. time versus load at a certain temperature, e.g. 500, 550, and 650° C. He found a strong similarity with *N*/*S* curves. The method is applied to a number of plain, low and high alloyed steels. From the time-to-failure line in short-time creep tests the creep resistance can be calculated by a formula developed by Stüssi.—T. G.

Void Nucleation in Creep of Metals. P. W. Davies and J. P. Dennison. (*Nature*, 1958, **182**, July 12, 131–132). A mechanism is advanced to account for nucleation in the absence of high concentrations of excess vacancies and of stress.

Creep and the Reduction of Tensile Strength of Steel Wire Particularly at Slightly Elevated Temperatures. W. Papsdorf and F. Schwier. (*Stahl Eisen*, 1958, **78**, July 10, 937–947). Tempered and heat-treated steel wire as used for prestressed concrete shows an inversion point in the time/strain curve. As-drawn wire does not exhibit such an inversion. Relaxation tests between 22° and 150° C were carried out for various stresses and times. At stresses of 55–60% of the U.T.S. and 1000 h, the reduction in U.T.S. is largest; for longer periods the effect of temperature diminishes. The study showed that tests at elevated temperature enable accurate relaxation curves to be derived. The phenomena involved are explained by strain-softening and strain-hardening effects in agreement with creep theory.—T. G.

Study of the Creep Recovery of a 12% Chromium–1% Molybdenum Steel. K. Bungardt, M. Bauer and H. Sychrovsky. (*Arch. Eisenhütt*, 1958, **29**, July, 415–422). Creep and recovery tests carried out between 500 and 600° C showed that creep is independent of long periods in which there was no load applied to the test pieces. Creep recovery follows a log. time law before attaining a final value. Recovery is also independent of the number of unloadings and of the total creep time under stress before recovery after final unloading. The different deformability of the individual domains as deduced from the theory is compared with experimental data.

Scratch Hardness. I. Relation to Cold-Working. T. Sutoki and T. Hikage. (*Sci. Rep. Res. Inst. Tohoku Univ.*, 1958, **10**, Apr., 85–96). Single and polycrystals were examined and a law similar to Meyer's for indentation was found. Change of scratch width with cold working was small whereas indentation hardness varies considerably. Scratch hardness is considered to be related to the annealed state rather than to the work-hardened state.

Unit Checks Scratch Depth. W. Umphrey. (*Iron Age*, 1958, **181**, June 12, 92–93). A description is given of an instrument developed by the Boeing Airplane Co., for measuring directly scratch depths between 0·03 and 0·00005 in.—A. G.

Study of Carburized Steel for Ball and Roller Bearing Material, 1st Report. T. Yoshida. (*Nippon Kinzoku*, 1957, **21**, Aug., 482–485). The author concludes that for Rockwell, Shore, and Vickers hardness tests to be meaningful the effective case depth should exceed the penetration of the indenter by a factor of ten, and the total depth of specimen should be twelve times as much as the test indentation. A non-destructive method for the measurement of the depth of case-hardening is proposed by the author, on the basis of Meyer's law of hardness. **2nd Report.** (Sept., 528–531). It was found that cracks appearing around the impressions of a ball hardness tester made in case-hardened steel correlated with residual stresses in the material. When the latter were tensile the cracks were radial and appeared at an early stage; when the residual stresses were compressive the cracks were circumferential—J. G. W.

Strain-Ageing Can be Controlled. E. R. Morgan. (*SAEJ.*, 1958, **66**, June, 50–51). Low-carbon sheet steels can be treated to remove any strain ageing by control of rate of migration, time available for migration and amounts free to migrate of C and H. Methods are outlined.

Effect of Hot Working Conditions on the Strain-Ageing of Low Carbon (0·18% C) Steels. Chang Tso-mei and Li Chien-hwa. (*Acta Met. Sin.*, 1957, **2**, (3), 249–259). [In Chinese]. The resistance of low-C steel to strain-ageing can be improved by controlling the hot-working conditions. The grain size and microstructure of killed steel may vary widely, but yet the impact values after strain-ageing remain satisfactory; with rimming steel strict control of grain size is necessary. Impact and tensile results show the effects of strain-ageing prominently. (12 references).

Study on the Properties of Vacuum-melted Steel. II. On Strain Age-hardening. R. Yamada, K. Yokoyama, T. Nakamura and F. Urushibara. (*Nippon Kinzoku*, 1957, **21**, Apr., 230–234). [In Japanese]. With vacuum-melted steels, the increase of tensile strength in the blue heat range was small or negligible. Strain-age-hardening after cold rolling was more delayed than with conventionally melted steels.—K. E. J.

Strain-Ageing, Work-Hardening and Inhomogeneous Deformation in Armco Iron after Static and Dynamic Deformation. H. P. Tardif and W. Erickson. (*J. Appl. Mech.*, 1958, **25**, June, 285–287). Preliminary results are given.

First National Congress of the Iron and Steel Industry [Mexico]. 1955. Changes by Ageing, in the Physical Properties of Various Types of Wire. (139–142). Mechanical test results for four qualities of steel wire (from 0·03 to 0·54% carbon) are given. The increased resistance to deformation can be beneficial (higher carbon contents), but when great wire flexibility is required dead mild steel should be used.

The Influence of Heat Treatmen on the Strain-Ageing of Aluminium-Killed Steel. P. Szeki. (*Acta Techn.*, 1958, **20**, (1–2), 145–151). [In English]. A study on the brittleness transition temperature by means of notch impact tests is described. Two steels with acid-soluble Al contents of 0·0136 and 0·0588% (acid soluble nitrogen 0·0055 and 0·0047%) were heat-treated in various ways and stretched 10%, machined to shape and aged 1 h at 250° C. Always the first treatment was heating to 920° to austenize. Explanations are advanced for the findings.

Thermal Stress and Thermal Stress Fatigue. L. F. Coffin, jun. (*Proc. Soc. Exper. Stress Anal.*, 1957, **15**, (2), 117–130). A review, with studies on stainless steel. Effects of temperature range, prior cold work, mean temperature and rate of cycling were studied and also the relation to mechanical strain cycling.

Thermal Stress Problems in Practice. R. U. Blaser. (*Proc. Soc. Exper. Stress Anal.*, 1957, **15**, (2), 131–142). Examples of welded structures, heat exchangers, boilers, and atomic energy applications are given and stress corrosion and effects in mechanical joints with or without gaskets are discussed.

Design Basis for Thermal Stresses. W. E. Cooper. (*Proc. Soc. Exper. Stress Anal.*, 1957, **15**, (2), 143–147). Operational conditions, stress and deformation analysis, design and fabrication are considered.

To-Days Trend in Ship Research. D. K. Felbeck. (*Weld. J.*, 1958, **37**, June, 265s–268s). Work on brittle fracture is reviewed.

High Temperature Intercrystalline Cracking. D. Kramer and E. S. Machlin. (*Acta Met.*, 1958 **6**, June, 454). [In English]. A letter. The fraction of the total grain boundary area occupied by cracks and voids is found to be proportional to the total strain at 1000° C. It is considered that this result provides evidence that the vacancy condensation mechanisms of creep are invalid.

On the Temper Brittleness of Steels (1st Report). Studies of the Si-Cr-Mn Structural Steel. T. Nakamura. (*Nippon Kinzoku*, 1957, **21**, Aug., 486–489). From an investigation based on a miniature impact test, it is reported that the higher the tempering temperature, the more pronounced the change of transition temperature with rate of cooling after tempering.—J. G. W.

A Study on the Brittle Fracture of Steels at Low Temperature (1st Report). On the X-Ray Test and Hardness Distribution Measurement of the Fractured Impact Test-Pieces. H. Tachibana and S. Kôda. (*Nippon Kinzoku*, 1957, **21**, Aug., 475–477). From X-ray examination of carbon steel specimens fractured at various temperatures, evidence has been obtained of the presence generally of plastic deformation, even when the fracture is of a cleavage type. However, in a fully embrittled specimen the plastic deformation was confined to a very thin layer adjacent to the fracture surface and apparently was equivalent to less than 2% strain.—J. G. W.

Studies on Heat-Checking of Iron and Steels. II. Experiments on Heat-Checking of Hot Die Steels. 2. T. Fujiwara. (*Nippon Kinzoku*, 1957, **21**, Mar., 149–153). [In Japanese]. Results are reported for disc-like specimens and mandrels made from 5% Cr–Mo–Si steel. With heat-treatment in charcoal-covered lead baths, intergranular oxidation proceeded, and heat checks formed at austenite grain boundaries. Heat checking is also related to surface scars produced by lathe tools or emery paper, even after electrolytic polishing. **III. Influence of Heating Time and Heating Temperature on Heat-checking.** (Aug., 494–498). Experiments with 5% Cr–Mo–Si steel specimens showed that the checks became more pronounced, the longer the heating time and the higher the temperature, particularly when the number of heating cycles was 1000. For any heating time the depth of checks was distributed according to an exponential function. Both depth and width of checks increased with heating time and temperature, but the number of checks reached a maximum at intermediate values of these.

Wear Resistance: Is Melting Point the Key? H. A. Unckel. (*Iron Age*, 1958, **181**, Mar. 20, 97–100). A study of wear was made using the following: sandblasting, abrasion with emery cloth and loose emery powder and metallic surfaces in sliding contact. The following materials were tested: Al, Al alloy, brass, Cu and iron. The order of wear resistance depended on the test method. In the sandblast tests, wear was not related to hardness of the material or other previously suggested properties, but was roughly proportional to the inverse of the absolute melting point of the materials.—D. L. C. P.

Effect of Hydrogen on Steel. H. Neuhaus. (*Stahl Eisen*, 1958, **78**, May 29, 750–753). This is a review of recent publications on solubility, estimation and diffusion of H_2 in solid and liquid steel and on its effect on their properties. The highest H_2 contents were observed in basic O.H. steels, whereas acid O.H. steels show the lowest levels.—T. G.

Diffusion and Solubility of Hydrogen in Alpha Iron and Silver. W. Eichenauer, H. Künzig and A. Pebler. (*Z. Metallkunde*, 1958, **49**, May, 220–225). The diffusion and solubility coefficients of hydrogen in α-iron were measured, using a new method which is described in detail. Good agreement was obtained with the values calculated from permeability and solubility by others.—L. D. H.

The Effect of Some Alloying Elements on the Activity Coefficient of Nitrogen in Liquid Iron. K. Sano and S. Minowa. (*Nippon Kinzoku*, 1957, **21**, Sept., 569–572). Solubility measurements on N_2 in Fe–V, Fe–Si, Fe–Ni, and Fe–Cr–Ni molten alloys were made at 1600° C at 160 mm and 760 mm pressure and the activity calculated by methods shown. The apparatus used is described.

Effect of Vanadium on Some Characteristic Properties of Cast Iron. G. Meckler. (*Stahl Eisen*, 1958, **78**, June 26, 900–906). The effect of additions of up to 0·9% V was studied on cast iron containing 1·15% Si used for casting rolling-mill rolls. V additions increased surface hardness and tensile strength at room and elevated temperatures. The effect is attributed to an increase in the cementite content of the iron.—T. G.

On the Effect of Vanadium and Tungsten on Die-casting Die Steel. Containing 5% Cr. S. Koshiba and T. Kuno. (*Nippon Kinzoku*, 1957, **21**, Mar., 157–160). [In Japanese]. A range of steels was examined for various properties of interest in die-casting of Al, Zn, etc. With vanadium contents in the range 0·30–1·10%, the optimum amount is 0·65%; addition of 1·30% of W then increases the tensile strength at 500–700° C.

Thorium and the Rare Earth Metals. Properties and Uses. (*Genie Civil*, 1958, **135**, Mar. 1, 108–112). Uses in iron are reviewed along with properties, production and other applications.

The New Precipitation-Hardening Stainless Steels for Super-Sonic Craft. A. C. Gilbraith. (*Austr. Mach. Prod. Eng.*, 1958, **11**, May, 23–28). Steels for honeycomb structures are reviewed with their heat-treatment and strength and strength-weight ratios. 17-7 PH (in conditions A, T, C and TH and a variant of A) and 17-4 PH and AM 350 steels are considered.

Survey Hot-Work Tool Steels for Aircraft and Missiles. R. J. Nekervis, C. H. Lund and A. M. Hall. (*Iron Age*, 1958, **181**, Feb. 27, 99–102; Mar. 6, 120–121). A survey of this subject by the Battelle Memorial Institute is presented. The materials are of particular interest in these applications due to their high strength and resistance to softening. Properties of some typical steels are given. One disadvantage of hot-work die steels is that they are not stainless, and some coatings have been developed. Welding and machining problems can usually be overcome.—D. L. C. P.

High-Strength Structural Steels. S. Kronmarck. (*Neue Hütte*, 1958, **3**, July, 433–442). A comprehensive review on requirements for, and the chemical composition of, high-strength structural steels produced in various countries. (54 references).—T. G.

Study on the Modified Spring Steel Containing a Small Amount of Tungsten. T. Akutagawa and Y. Yabuki. (*Ann. Rep. Eng. Res. Inst. Tokyo Univ.*, 1957, **16**, Sept., 50–55). [In Japanese]. Mechanical properties of a spring steel containing 0·15% W cold-rolled to 0·27 mm thickness and heat-treated in a salt bath furnace, are described. W has almost no effect on hardness or elasticity, but under certain conditions improves the fatigue properties.—K. E. J.

The Development of a Weldable Manganese–Titanium–Aluminium Steel St 52 in Hungary. G. Kristóf, E. Szücs, J. A. Veró and B. Zorkóczy. (*Neue Hütte*, 1958, **3**, July, 425–432). The authors review the composition and properties of steel St 52 produced in various countries and the effect of Ti on the weldability of these steels. They report on the development of a Mn–Ti–Al steel in Hungary and point out the difficulties that exist in that country for producing high-quality steel. Deviating from the specification MOSZ 6290-57 the analysis of the commercially produced steels vary within the following limits: C 0·15–0·18, Mn 1·0–1·3, Si 0·25–0·4, and Ti 0·15–0·05%. Testing for weldability and applications are dealt with.—T. G.

An Investigation of Carburising Grade Boron Steel. Kuan Chi-piao and Li Lin. (*Acta Met. Sin.*, 1956, **I**, (3), 255–264). [In Chinese]. To replace a chromium steel, a carburizing-grade boron steel was chosen, containing < 0·30% Cr, 0·30% Ni and 0·15% Mo. The boron hardenability factor decreases with increase in carbon content, and a linear relationship between the two is given. For the best properties of the boron steel, the max. carbon content of the carburized surface should be <1%.—K. E. J.

An Investigation of Boron–Molybdenum Constructional Steel. Chi Min-wei and Li Lin. (*Acta Met. Sin.*, 1956, **I**, (3), 265–277). [In Chinese]. Properties of low-carbon B–Mo steels (including max. stress > 60 kg/mm²) are given, and the steel is recommended for constructional use. Boron increases the mechanical strength of 0·50% Mo steel by altering the dispersion of carbide and ferrite in the microstructure after normalizing. The max. diameter of the steel bar should not exceed 75·2 mm.—K. E. J.

[Compositions of] Standard Stainless Steels, Wrought and Cast. (*Met. Prog.*, 1958, **73**, (6), June, 96B).

Guide to Materials Standards and Specifications Part 2. Iron and Steels. S. P. Kaidanovsky. (*Mat. Design Eng.*, 1958, **47**, April 110–114). The scope and activities of U.S. Standards organizations are shown. A table of specifications is given.

How the 200 Series Compares with 18–8 Stainless Steels. G. A. Sands and M. B. Keady. (*Mat. Design Eng.*, 1958, **47**, April, 120–124). Mechanical, fabrication and corrosion characteristics of Cr–Ni–Mn stainless steels are compared with 18–8.

Coming: Better Thermenol Alloys. W. J. Buehler and C. G. Dalrymple. (*Met. Prog.*, 1958, **73**, May, 78–81). The addition of 0·05–0·1% C and 0·2–0·4% Zr to wrought alloys containing 10–18% Al and 2–4% Mo (Thermenol) improved mechanical properties and restricted grain growth at elevated temperatures.

Stainless Steels and Other Ferrous Alloys. W. A. Luce and J. H. Peacock. (*Ind. Eng. Chem.*, 1958, **50**, Sept. Part II, 1482–1488). A review of these metals as materials of construction with reference to mechanical and anticorrosion properties, welding, working and finishing, included are high-Si iron, Fe–Ni alloys and austenitic Fe–Mn steel. (137 refs.).

Chromium Gives Stainless Properties to Iron–Aluminium Alloys. B. King, J. J. Mueller, N. N. Ida and F. G. Tate. (*S.A.E.J.*, 1958, **66**, Oct., 48–53). The development of the Fe–Al alloys, their high temperature resistance and the improvement in room-temperature ductility, weldability and work-hardening susceptibility by suitable alloying are described. The properties of 5·5%Al–9·5%Cr and 7·5%Al–5%Cr–1%Nb–½%Ti

alloys are given and compared with standard stainless grades.

High-Strength Non-Magnetic Alloys. H. Bernstein. (*Mat. Design Eng.*, 1958, **48**, Aug., 104–106). Safety tools are discussed. Stainless steels and non-ferrous materials are specified.

Research on Steel. (*Elect. Times*, 1958, **134**, Nov. 20, 777). A brief account of Stewarts and Lloyds new laboratory.

METALLOGRAPHY

High-Performance Steels. E. A. Loria. (*Mach. Design*, 1958, **30**, Sept. 4, 111–115). A general discussion of microstructure and the effects of the various phases on hardenability and other properties.

Investigation of Non-Deformed Steel by Means of the X-ray Microscope. I. M. Ya. Fuks and L. Ya. Gol'dshtein. (*Fiz. Met.*, 1958, **6**, (3), 512–516). X-ray investigation with microbeams of the fine structure of heterogeneous alloys by means of the sharp focusing tube system of B. Ya. Pines is described. In carbon steel type 25 in a non-deformed condition, the crystals after normalizing and tempering at high temperature, consist of a small number of relatively large and disoriented fragments of nearly uniform lattice parameters.—L. H.

On the Paraffin-Coated SUMP Two-Step Replica Method. Y. Tanabe. (*Nippon Kinzoku*, 1956, **20**, Dec., 663–665). Details are given of the preparation and shape limitation factor of a SUMP replica; this, normally used for optical microscopy, is applied to electron microscopy. It can be prepared in 1½ h.—K. E. J.

A Simple Apparatus for Electrolytic Polishing of Metallographic Specimens. F. Brossa and C. Sari. (*J. Sci. Inst.*, 1958, **35**, Nov., 425–426). A device made in the laboratory is described and instructions for iron and Al alloys are given.

The Determination by Oxidation of Austenitic Grain Size in Mild Steel. P. Széki. (*Acta. Techn.*, 1958, **21**, (1–2), 79–86). [In English]. A polished specimen is heated in a tube furnace in a stream of N_2 and the O_2 always present in the commercial gas does the oxidation necessary to reveal the grain boundaries. The N_2 is led through H_2SO_4, through a tube furnace packed with cast iron chips and through alkaline pyrogallol and again through H_2SO_4 and then to the furnace containing the specimen. Results obtained at 970°, 1050°, 1070°, 1120°, 1150° and 1170° are shown. At the higher temperatures, grain coarsens and twin structures appear and a mosaic of crystals not in conformity with the original boundaries appears.

A General Scheme for the Examination of Precipitates and Inclusions in Steels. G. R. Booker and J. Norbury. (*Brit. J. Appl. Phys.*, 1958, **9**, Sept., 361–365). The extraction replica method is used and optical, electron, X-ray and spectrographic methods of examination are used.

Factors Controlling the Grain Size of 5 Per Cent Chromium Hot Work Die Steels. R. F. Harvey and C. T. Fletcher. (*Steel Proc.*, 1958, **44**, Mar., 129–136, 165). Effects of austenizing temperature, time, composition, forging conditions and annealing conditions on intercept grain size are reviewed. Si, Cr, W and Mo and various combinations of these are considered. Tests on all these factors are described.

Study on Strain-Tempering. VIII. On the Effect of Strain-Tempering on Recrystallization and Grain Size. K. Honda and T. Sano. (*Nippon Kinzoku*, 1956, **20**, Dec., 659–663). Results are given for 50% Fe–Ni sheets cold-rolled under various conditions. Strain-tempering easily induces grain growth, the max. size being influenced by temp. and stress. Recrystallization texture is sharper than with annealing and secondary recrystallization is hastened, starting at about 1050° C in H_2 which is more effective than N_2 or air in promoting it.—K. E. J.

Effect of the Rate of Heating on the Development of "Hereditary" Structure of Austenite in Previously Quenched Cr Steels. V. G. Gorbach and V. D. Sadovskii. (*Fiz. Met.*, 1958, **6**, (1), 106–109). The austenite structure which is formed when previously quenched steel is heated depends largely on the rate of heating. When steel which has been hardened, but not tempered is subjected to rapid heating, the initial austenite grain is restored. The higher the Cr content of the steel, the lower the rate of heating required to restore the grain. The same applies to the case of hardened and tempered steel which is heated slowly.—R. S.

Austenite Transformation and Incubation in an Alloy Steel of Eutectoid Carbon Content. R. A. Grange, P. T. Kilhefner, jun. and T. P. Bittner. (*A.S.M. preprint* 93, 1958, pp. 19). A continuous cooling transformation temperature diagram was experimentally determined for a Ni–Cr–Mo steel whose carbon content formed neither pro-eutectoid ferrite nor pro-eutectoid carbide. An explanation is given for the unsatisfactory results obtained from the proposed methods for this steel.—E. E. W.

The Transformations of Austenite: The Metastable Lines in the Fe–C Equilibrium Diagram. M. Doi. (*Bol. A.B.M.*, 1958, **14**, Jan., 95–110). [In Portuguese]. These lines are calculated on the basis of the free energies of austenite, ferrite and cementite, these having been discussed in turn. The A_3 and Acm lines as calculated correspond fairly well to determined results. The GPA line (from A_3 on the ferrite side) shows little variation of carbon concentration below 600° C which suggests there is no direct relationship with the Ar^{11} line. The line marking the equal free energies of austenite and ferrite is roughly parallel to the Ar^{11}, the line for equal free energies of austenite and ferrite–cementite mixtures is roughly parallel to the Ar^{1} line.—P. S.

Studies on Heat-Treatment of High-Alloy Tool Steels. I. On Retained Austenite in Hardened High-Carbon High-Chromium Steel. T. Nemoto. (*Nippon Kinzoku*, 1956, **20**, Dec., 669–673). Studies were made on steel containing 2·17% C and 12·57%Cr. At room temp. from 10 to nearly 100% of retained austenite is contained in specimens oil-quenched from 900–1200° C. The M_s point is below room temp. for quenching temp. below 1150° C. The retained austenite in specimens oil-quenched from below 1100° C can decompose into bainite or pearlite, but that formed at quenching temp. above 1150° C decomposes only into pearlite. The isothermal transformation diagrams show that austenite is metastable in the intermediate zone. (30 references).—K. E. J.

Stability Relationships in Cast Irons and their Representation. W. A. Oates. (*J. Australian Inst. Met.*, 1958, **3**, May, 76–83). The thermodynamics and kinetics of precipitation of carbide and graphite in cast irons are discussed. The value of carbon potential-temperature diagrams in interpreting the behaviour of cast irons is stressed.—A. G.

The Electron Microscope as a Metallurgical Tool. W. MacFarlane. (*Journal of the Metallurgical Club*, 1957–8, (101, 31–34). A replica technique for the examination of fatigue cracks is described and the observations are summarized.

Diamond Abrasives in Metallographic Polishing. L. E. Samuels. (*J.B.S.C.R.A.*, 1957, Dec. reprint, pp. 4). The advantages and limitations, comparative value and costs are surveyed.

Electrolytic Polishing for Metallography. C. Johnson. (*AB Met. Digest*, 1958, **4**, Jan., 4–15).

A General Consideration of Trace Elements With Particular Reference to Metallography. A. Portevin. (*Fond. Belge*, 1958, **28**, May, 147–153). A number of examples illustrating the effects of impurities and trace elements on the physical, chemical and metallurgical properties of metals are presented and discussed.—B. C. W.

Application of Radioisotopes to the Determination of the Origin of Non-Metallic Inclusions in Steel. K. Skuin. (*Technik*, 1958, **13**, July, 489–492). The author reviews two methods of the application of radioisotopes in the steel industry: The Russian Grigoryan and Samarin method of the "marked atoms" and a Polish one. New regulations on the use of radioisotopes in the Soviet Union will prevent any studies involving radioisotopes of a half-life of more than 15 days being used in industry. Even if the studies could be carried, no new results could be expected.

[**Metallographic Researches**]. (*Metallografiska Institutets Forskningsverksamhet*, 1956, Jan.-June, July-Dec.; 1957, Jan.-June, pp. 26, 27, 29). [In Swedish]. **Electron Microscopy of Metals.** S. Modin and H. Modin. ((10), 7–8, (11), 4–6). An account of the examination of carbide, carbon, cementite and other particles in steel. **Isothermal Conversion of Austenite.** S. Modin and H. Modin. ((10), 4–7). The authors also deal with pearlite reactions and bainite formation. **Isolating Carbide Particles in Steel.** S. Modin and H. Modin. ((10), 15–16). A brief description of a new method developed at the Institute for isolating carbide particles in carbon steel. **Soft Annealing of Pearlite.** S. Modin and H. Modin. ((10), 17–18; (12), 6–8). **Atomic Arrangement in the Cubic Al, Fe and Si Phase.** P. Spiegelberg and L. Danielsson. ((11), 6–11). **Graphite Growth when Separating Primary Ferrite.** ((11), 19–21). **Criteria for Eutectic and Peritectic Reactions.** M. Hillert. ((12), 15). **On the Micro-Structure of Martensite.** H. Modin. ((12), 17–18). **The Thermodynamics of Martensite Conversions.** M. Hillert. ((12), 13–14). **The Kinetics of Conversions under Stable Conditions.** M. Hillert. ((12), 15–17).

An Investigation on Striated Inclusions in Mild Steel Plates. Chuang Yu-Chih and Wu Cheung-hang. (*Acta Met. Sin.*, 1956, **I**, (2), 155–164). [In Chinese]. Microscopical and X-ray examinations show that the main constituents of the inclusions are the same as are found in the attacked layer of fireclay refractories which predominantly consist of mullite and cristobalite. The inclusions probably arise from attack of refractories by MnO or MnO.FeO.—K. E. J.

An Investigation on Stratified Inclusions in Mild Steel Plates. Lee Hsun, Chen Chi-tse, Lee Che-pow, Yan Sho and Han Yao-wen. (*Acta Met. Sin.*, 1956, **1**, (4), 301–309). [In Chinese]. The nature and appearance of the inclusions in medium-thick plates are classified into three types according to different positions of the rimming ingots from which the plates were made, and their origins are discussed in terms of works data.—K. E. J.

The Loss of Non-Metallic Inclusions in Steel During Electrolytic Separation. Shih Chang-hsu, Lee Tai-chung and Chao Shu-hsi. (*Acta Met. Sin.*, 1957, **2**, (3), 295–298). [In Chinese].

Carbides Formed in the Low Temperature Decomposition of Austenite. V. G. Permyakov. (*Metallov. Obrabotka Met.*, 1958, (3), 24–29). Five steels were examined and austenizing conditions were established and complete solution of C was secured with protection from decarburization and scaling. Magnetic and dilatometric measurements were then made and the carbides were examined. The similarity between isothermal decomposition of austenite and the tempering of quenched steels was confirmed. Three types of carbide were found. Fe_3C with a Curie point of 380° is produced at low temperatures, above these it transforms into an intermediate carbide which goes to cementite.

The Effect of Thermal Grooving on Grain Boundary Motion. W. W. Mullins. (*Acta Met.*, 1958, **6**, June, 414–427). [In English]. A theory based on the Gibbs-Thompson formula relating curvature to chemical potential is developed to describe the dynamics of thermal groove formation at a moving boundary or one inclined to the surface plane. It is predicted that a boundary will become anchored at the surface if the angle that it makes with the surface is less than some critical value. The effect of specimen thickness on grain growth is also considered.

Veining in Ferrite. A. Hultgren, Å. Josefsson, E. Kula and G. Lagerberg. (*Jernkonts.*

Ann., 1958, **142**, (4), 165–202). Deformation structures in ferrite have been examined microscopically, with particular reference to veining, defined as sub-boundaries. Increased regularity of veining network was found at higher deformation rates and temperatures, and with a large grain size. Three types of veining were observed in the same specimen, termed ridged, grooved and level, conditions of formation being related to orientation, rate of cooling and C and N content. The conditions governing the occurrence of the three types of veining are studied. (27 refs.).—L. D. H.

The Mechanism of Formation of Band Structures. P. G. Bastien. (*Tech. Mod.*, 1958, April, 121–129). Band structure is related to dendritic segregation during cooling. The mechanism of its occurrence is analysed and the rôles of carbon, phosphorus and minor elements such as As and Sn are considered.

Effect of Boron on the Kinetics of Austenite Grain Growth and the Initial Austenite Grain Size. A. M. Tarasov. (*Metallov. Obra. Met.*, 1958, (1), 17–20). The range from 0·0015–0·01% B is covered. Laboratory studies in a 100 kg basic-lined induction furnace are described in which steel was melted, ferroboron added and the heats cast into 44 lb ingots which were forged and curburized at 920°, 1100° and 1100° C for 5, 10 and 20 h to reveal grain size. The critical content of B in the Cr–Mn steel used was 0·0015–0·003%, such a steel shows grain growth at 1000° in 20 h. 0·005% B is undesirable and 0·006% unacceptable as grain growth is then rapid. An acicular structure was noted after quenching and tempering.

The Mechanism of Formation of Widmanstätten Structure of Alpha-Iron in Hypoeutectoid Carbon Steels. Ko Tsun (T. Ko) and Zhao Gia-zheng. (*Acta Met. Sin*, 1956, **I**, (2), 201–208). [In Chinese]. This structure produced in 0·27, 0·40 and 0·52% carbon steels was always accompanied by a surface relief of the type associated with bainite transformation. In slowly-cooled specimens, and in specimens with fine austenitic grains, when the structure does not appear, grain-boundary ferrite probably prevents the formation of bainite. It is shown that austenite may decompose by the bainite transformation at temperatures as high as 750° C.—K. E. J.

Aluminium Nitride Precipitates in α-Iron. G. R. Booker and J. Norbury. (*Nature*, 1958, **182**, July 26, 255–256). Electron micrography of plastic replicas showed long narrow rods and small angular particles to be present. Electron diffraction patterns from both were obtained, both giving the AlN pattern without extra lines.

Intermediate Phases in the Iron-Tungsten and Cobalt-Tungsten Binary Systems. E. C. Van Reuth. (*WADC Techn. Report* 57–717; *ASTIA Document No. AD* 142258; *PB* 131627 075; 1957, Dec. pp. 23). Fifty-three alloys were examined for sigma-phase. Metallographic and X-ray methods were used and no α-phase was found, but Xi-phase (M_3W_2) was present, originally labelled Mu by Arnfelt and Westgren. Changes in the diagrams were found to be necessary.

Investigation of the Fe–Mn–Cr–N–C System for Heat-Resistance and Oxidation Resistance between 1 200° F and 2 000° F. C.-M. Hsiao and E. J. Dulis. (*WADC Tech. Report* 57–242; *ASTIA Document AD* 142086; *PB* 131563 400, 1957, Nov. pp. 144). Phase boundaries were established for stable austenitic Cr–Mn–C–N steels and the effects of these elements and of V, W, Mo and Nb on microstructure, room and elevated temperature properties, and a nomogram is given for these steels and their properties. They are less resistant to oxidation than Cr–Ni steels, but have excellent strength and ductility.

The Plutonium–Iron System. P. G. Mardon, H. R. Haines, J. H. Pearce and M. B. Waldron. (*J. Brit. Nuclear Energy Conf.*, 1958, **3**, Oct., 252–258). The equilibrium diagram is shown and compared with one published in Russia. The compounds Pu_4Fe and $PuFe_2$ are found and eutectics between δ-plutonium and Pu_4Fe and between $PuFe_2$ and γ-iron.

CORROSION

Mechanics of Corrosion. H. E. LaBour. (*Corros. Techn.*, 1958, **5**, Oct., 320–322). The different types of corrosion are classified with illustrations of the mechanical effect on the corroded parts (pump casings).—A. G.

New Corrosion Index Shows Nation's Rust Pattern. (*Iron Age*, 1958, **182**, Aug. 28, 54–56). The Rust-Oleum Corp. has been carrying out for many years, a survey on the liability of atmospheres throughout U.S.A. to cause rusting; some results are presented. The Rust Index used is the number of years and months required to corrode an uncoated 28-gauge steel test panel to a severe degree Values range from 3 to over 15. Values are given for major cities, and a map illustrates the distribution of the Index.—D. L. C. P.

Corrosion Mechanisms and Materials Selection Methods. F. L. LaQue. (*Chem. Eng. Prog.*, 1958, **54**, Nov., 58–64). A review of theories, investigations, tests and related topics for chemical environments.

Design From the Viewpoint of Corrosion. W. D. Clark. (*Met. Rev.*, 1958, **3**, (11), 279–325). Choice of materials, testing, factors in corrosion and corrosion processes, environmental factors, especially those rendering conditions abnormal, geometrical and metallurgical factors and protective measures are considered in general terms. (75 refs.).

Design Factors in Corrosion Control. R. V. Jelinek. (*Chem. Eng.*, 1958, **65**, Nov. 17, 151–154). In a general way the avoidance of galvanic couples, stray currents and concentration cells, localized stress, surface smoothness and surface—to volume ratio are considered.

Atmospheric Corrosion at Karaikudi. K. S. Rajagopalan and G. Ramaseshan. (*J. Sci. Indust. Res.*, 1958, **17B**, Oct., 438–439). A letter. Rates of corrosion of abraded iron and zinc for every month of the year are recorded.

Corrosion of Iron and Steel. ASTM Committee A-5. (*ASTM preprint*, 1958, (3), pp. 15). Revisions are noted and tentatives issued for weight of coating on Al-coated iron or steel articles and for long terne iron or steel sheets, coils and cut lengths.

Galvanic Corrosion. II. Effect of pH and Dissolved Oxygen Concentration on the Aluminium-Steel Couple. M. J. Pryor and D. S. Keir. (*J. Electrochem. Soc.*, 1958, **105**, Nov., 629–634). High-purity Al protects steel completely in chloride solutions at pH 0·2–14·0. Weight losses of the Al are at a minimum at pH 4–10. Current fluctuates because the oxide film on the steel thickens in an erratic manner. Above and below this range corrosion is greater with evolution of H_2 which reduces the oxide films on the steel and the current is very steady.

Underground Corrosion. (*Engineer*, 1958, **206**, Dec. 5, 905–907). A report on work in progress by the N.B.S. is given. Large numbers of steel specimens are illustrated after exposure. Galvanized and non-ferrous metals were also tested.

Does Higher Fuel Efficiency Increase Corrosion? N. Seely. (*Corros. Techn.*, 1958, **5**, Nov., 355–356). The use in high-temperature oil-burning plant of Slipco, an organic additive to prevent corrosion from V_2O_5 at high temperatures, is described. The inhibiter also contains an additional substance to inhibit H_2SO_4 deposition at lower temperatures by promoting a protective inert layer on internal surfaces.

Role of Condensation in the Corrosion of Steel by Moisture and Sulphur Dioxide. B, Sanyal and D. V. Bhadwar. (*J. Sci. Ind. Res.* 1958, **17B**, July, 287–288). An experimental set-up is described, which appears to demonstrate that keeping panels free from condensate practically eliminates corrosion.

Sulphuric Acid Corrosion in Oil-fired Boilers; Studies on Sulphur Trioxide Formation. D. A. Anderson and F. P. Manlik. (*Trans. A.S.M.E.*, 1958, **80**, Aug., 1231–1238). A small experimental boiler was fired with a distillate oil to which compounds were added to simulate the thio-compounds and metals found in residual oils. SO_3 was measured indirectly from corrosion and sulphate formation. Ni, Fe, Na and V compounds in the fuel reduced corrosion and only iron-containing deposits significantly catalysed SO_3 formation. Na and V reduced corrosion, but formed deposits which accelerated it.

High Temperature Hydrogen Sulphide Corrosion in Refinery Experience. P. W. Sherwood. (*Corros. Techn.*, 1958, **5**, Oct., 326–329). Catalytic cracking and desulphurization generate H_2S at high temperatures which results in scaling and impaired heat transfer. Temperature rather than H_2S concentration is the major factor in this corrosion. Various remedies are suggested; for steel HCl is applied at regular intervals to remove the scale.—A. G.

Corrosion of Refinery Equipment during Acid Cleaning. K. R. Walston and A. Dravnieks. (*Corrosion*, 1958, **14**, Dec., 571t–577t). The use of HCl is discussed. Inhibitors are needed to protect metal, but these must not retard solution of scale. Corrosion rates for metals in inhibited 5%HCl are given and effects of inhibitors on the dissolution of oxides and sulphides are shown. Safety precautions are noted, also the accelerating effect of H_2S on corrosion and of ferric iron salts.

Corrosion Resistance of Austenitic Nickel–Chromium Steels. W. Katz. (*Wire*, 1958, Aug., 27–31). The resistance of these steels is explained, followed by a description of the principal forms of corrosive attack and illustrated by means of the most important conditions bringing this about, for the various types of steel in this class. These are listed in a comparative table of U.S., British, and German Standard specifications.—J. G. W.

Corrosion Problems in Processing Nuclear Fuels. W. G. O'Driscoll and T. E. Evans. (*Ind. Chem.*, 1958, **34**, Nov., 585–588). Uses of stainless steel are referred to.

Intercrystalline Stress-Corrosion Cracking of Austenitic Stainless Steel in Caustic Solutions. P. P. Snowden. (*Chem. Ind.*, 1958, Dec. 20, 1692). Rapid attack has been observed even in 1%NaOH and fracture may take place in a few h at 10 tons/in² at 300° C. Addition of silicate causes the attack to become wholly intercrystalline.

Cathodic Protection and High Resistivity Soil—A Sequel. H. C. Van Nouhuys. (*Corrosion*, 1958, **14**, Dec., 583t–587t). A further report on a system of protection for 350 miles of bare 8-in pipe in an ultra-high resistivity soil. The leak record is reviewed, and a summary of savings to be expected, and precautions to be taken are given.

New System to Beat Hull Corrosion. Cathodic Corrosion Control Ltd. (*Corros. Techn.*, 1958, **5**, Aug., 274–275). An automatic unit is described for maintaining a predetermined potential difference between hull and electrode. The system uses A.C. and rectifiers and lead alloy anodes. The advantages of the electrical system as compared with the use of Mg or Zn anodes are stressed.—T. G.

Cathodic Protection under Present Freight Conditions. Seaguard Ltd. (*Corros. Tech.*, 1958, **5**, Aug., 254–256). The use and advantages of spherical collared magnesium anodes for the cathodic protection of black oil tankers and of deep tanks of cargo ships are described, the beneficial effects of cathodic protection to ships while being laid up under present world freight conditions stressed and the costs of the protection installation discussed.—T. G.

Cathodic Protection: Its Effect on Shipbottom Coatings. W. J. Francis, H. J. Preiser and F. E. Cook. (*J. Am. Soc. Naval. Eng.*, 1958, **70**, Aug., 401–421). Tests are described on panels coated with a large number of undercoat and top coat antifouling paint and enamel systems. It is recommended that cathodic protection be used with vinyl, hot plastic or cold plastic Navy standard paint systems and that further tests be made on vinyl and epoxy mastic coatings. Controlled potentials of − 0·7, − 0·8 and − 0·9 V should be tried with the more promising coatings.

Reducing Cathodic Protection Costs in Tankers. L. R. Page. (*Corros. Techn.*, 1958, **5**, Aug., 257–259). The author stresses the importance of correct design of cathodic

tentatives are issued for uncoated stress-

protection systems as opposed to rule-of-thumb methods to efficient protection of tankers. Long-time protection lasting up to four years and using 127-lb finned Mg anodes, anode attachment, use of epoxy resin paints, zinc anodes and propeller protection are dealt with.—T. G.

Ships' Bottom Paints in Relation to Cathodic Protection. T. A. Banfield. (*Corros. Techn.*, 1958, **5**, Aug., 243–246). Principles and application of cathodic protection to ships' bottoms are reviewed. Painting of the bottom is still necessary as the protective current requirement of bare steel in sea-water is very high. The surface around a cathodically protected ship reacts slightly alkaline, there is also a risk of H_2 evolution; the paints used must withstand these conditions which are particularly severe near the anodes.—T. G.

ANALYSIS

Chemical Analysis of Metals. A.S.T.M. Committee E-3. (*A.S.T.M. preprint*, 1958, (60); pp. 16). Findings of Task Groups in the ferrous metals division are reported. (Specifications given are non-ferrous).

Simple Test Identifies Stainless. (*Iron Age*, 1958, **182**, Nov. 13, 147). The following test is described for differentiating series 200 (low Ni) from series 300 (Cr–Ni) stainless steel. Place 2 drops HNO_3 (S.G. 1·42) and 1 drop HCl (S.G. 1·19) on the specimen; add 2 drops water; add excess of sodium bismuthate. The series 200 steel gives a dark red-brown spot, the series 300 steel a tan spot.—D. L. C. F.

Determination of Gases in Metals. (*ASTM, S.T.P.*, 222, 1958, pp. 60). **Two Apparatus for the Determination of Gases in Metals.** D. L. Guernsey and R. H. Franklin. (3–14). The vacuum fusion method is used, H_2 in steel is determined. **The Application of Vacuum Fusion to Gas-Metal Studies.** A. L. Beach and W. G. Guldner. (15–24). Apparatus is shown and analysis of Ni, Mo, Si, Ta and Ge are described. **Oxygen Determination Using a Platinum Bath and Capillary Trap.** W. G. Smiley. (25–32). **Bromination-Carbon Reduction Method for the Determination of Oxygen in Metals.** M. Codell, G. Norwitz and S. Kallmann. (33–40). The method fails for steels containing oxide inclusions. **Emission Spectrometric Determination of Oxygen in Metals.** V. A. Fassel, W. A. Gordon and R. W. Tabeling. (41–60). Steel is included. (38 refs.).

Ion Exchange and Chromatography in Analytical Chemistry. (*A.S.T.M. S.T.P. No.* 195, 1958, pp. 57). The symposium was made up of **Ion Exchange in Analytical Chemistry.** R. Kunin. (3–10). **Ion Exchange in Analytical and Radiochemistry.** J. E. Hudgens, jun. (11–25). (76 refs.), and **Metal Separations by Anion Exchange.** K. A. Kraus and F. Nelson. (27–57). (47 refs.).

Thermogravimetry and Its Applications in Analytical Chemistry. Z. F. Shakhova and E. N. Semenovskaya. (*Zavods. Lab.*, 1956, **22**, (12), 1430–1435). A review describing Russian apparatus. Mainly analytical uses are described on the stability of precipitates, but analysis of raw materials (lime–$Mg(OH)_2$–$CaCO_3$–dolomite) have been reported.

The Determination of Chromium by a Solvent-Extraction Method. P. D. Blundy. (*Analyst*, 1958, **83**, Oct., 555–558). Chromate is produced by oxidation with hexanitratocerate and extracted with *iso*butyl methyl ketone from M HCl at not more than 10° C. The chromate is washed out and determined with diphenylcarbazide.

The Determination of Cobalt in Iron and Steel. R. C. Rooney. (*Metallurgia*, 1958, **58**, Oct., 205–208). Co is determined in the range 0·001% to 1% by preliminary separation of Fe and Cu with cupferron, and determining the Co spectrophotometrically.

On the Simultaneous Potentiometric Determination of Molybdenum and Tungsten in Alloy Steels. R. Suárez Acosta. (*Anal. Real. Soc. Españ. Fis. Quim.* 1958, **54** (B), Apr., 285–290). [In Spanish]. A new method is proposed: this consists of reducing the alloy steel solution with metallic zinc and chromous sulphate and reoxidizing with a standard potassium dichromate solution. The dichromate is preferably standardized against a steel of known composition. Details of the procedure, and some results, are given, e.g. a steel containing 16·12%W and 0·55%Mo gave figures of 15·9% and 0·54% respectively on analysis in this way. When the elements are present in such disproportionate amounts, a hydrochloric acid-solution ratio of at least 5 : 1 is recommended.—P. S.

The Determination of Molybdenum and Tungsten: 4-Amino-4′-Chlorodiphenyl as Precipitant. Liang-Shu-Chuan and Wang Shen-Jung. (*Acta Chim. Sin.*, 1958, **24**, (1), 117–122). [In Chinese with English Summary]. Conditions for use for W are given. It precipitates Mo at pH 1·8–2·8, but the precipitate is somewhat soluble.

The Determination of Nickel by a Solvent-Extraction Method. P. D. Blundy and M. P. Simpson. (*Analyst*, 1958, **83**, Oct., 558–561). U, Th, Cu, Fe and Cr may be present. The 4-methyl*cyclo*hexane—1 : 2—dione dioxime complex is extracted with toluene and the colour density is measured. Interference by Cu is supressed with thioglycollic acid and Fe by tartaric acid, which also prevents hydrolysis of Th.

The Reduction of Hexavalent Tungsten. H. M. Stevens. (*Anal. Chim. Acta*, 1958, **19**, Oct., 334–338). WCl_6 in ethanol-HCl can be reduced completely by Zn and a pure quadrivalent salt solution obtained.

Determination of Small Amounts of Silicon in High-Purity Iron. H. G. Short and A. I. Williams. (*Analyst.*, 1958, **83**, Nov., 624–627). Pile activation is used.

***p*-Bromomandelic Acid: Reagent for Zirconium.** E. J. Newman. (*Organic Chemical Reagents, Monograph* 36, 1958, pp. 4).

On the Separation of Vanadium, Molybdenum and Tungsten with Paper Chromatography. Tzou Shih-Fu and Liang Shu-Chuan. (*Acta Chim. Sin.*, 1958, **24**, (5), 383–387). Butanol–H_2O_2–HNO_3 with or without dioxane or benzoylacetone are used as eluents. Mixtures of solvents with persulphate were less successful.

Rapid Determination of Phosphorus in Carbon Steels and Cast Irons by Colorimetry and Photoabsorptiometry. R. de la Cierva. (*Inst. Hierro Acero*, 1958, **11**, Apr.-June, 85–90). [In Spanish]. The need for stage control analysis of phosphorus in certain steels is indicated and the methods available for phosphorus determination are reviewed briefly. A method which enables its determination in 7–12 min is proposed and details of the procedure are given. A colour complex is formed by means of an acid solution of ammonium molybdate and compared with standards; for final samples, and for greater accuracy, a photoelectric absorptiometer is used. The theory of the process and typical results are discussed. With low phosphorus contents, the errors are estimated as less than 0·005 and 0·001% respectively for the two methods. (19 references).—P. S.

Improved Method for the Determination of Nitrogen in Steel. S. Wakamatsu. (*Nippon Kinzoku*, 1956, **20**, Aug., 449–452). [In Japanese]. The normal time-consuming digestion process is replaced by solution in (1 : 1) HCl in an Erlenmeyer flask, followed by distillation of ammonia as usual, with no significant increase in experimental error.

Determination of Manganese and Chromium in Steel, Using a Cobalt–Copper–Nickel Catalyst. G. M. Gansburg and R. E. Dlugach. (*Ukrain. Khim. Zhur.*, 1957, **23**, (4), 533–536). A method for the determination by one weighing of Cr and Mn in high-Cr steels, Cr–Ni steels, and low-Cr steels, and of Mn in plain C steels, using a Co–Cu–Ni catalyst is described.

Polarographic Determination of Nickel in Cobalt Salts. J. Doležal and P. Hofmann. (*Coll. Czechoslovak. Chem. Comm.*, 1955, **20**, (1), 151–157). [In Russian].

A Contribution to the Colorimetric Determination of Cobalt. J. Michal and J. Doležal. (*Coll. Czechoslovak Chem. Comm.*, 1956, **21**, (6), 1413–1417). [In German]. The yellow-brown colour of the ethylenediamine complex is used.

Use of Amino-Compounds in the Polarography of Inorganic Substances. VI. Cobalt Determination in Steels and Ores. J. Doležal and J. Novak. (*Coll. Czechoslovak Chem. Comm.*, 1958, **23**, (5), 866–872). [In German]. Ethylenediamine—caustic potash solution is used.

Simultaneous Photometric Determination of Vanadium and Molybdenum Using Pyrocatechol. V. Patrovský. (*Coll. Czechoslovak Chem. Comm.*, 1955, **20**, (6), 1328–1331). [In Russian].

Polarographic Determination of Copper and Iron. J. Doležal and P. Hofmann. (*Coll. Czechoslovak Chem. Comm.*, 1955, **20**, (1), 147–150). [In Russian]. Ferric iron and Cu are determined in ethylenediamine tartrate and K pyrophosphate solution.

On the Method for the Determination of Magnesium in Spheroidal Graphite Cast Iron. S. Monita, R. Ozaki, and S. Hatano. (*Suiyokwai-Shi*, 1957, **13**, June, 279–282). The oxine volumetric method is described. It is observed that the accuracy of spectrometric measurements is greater on chill-cast specimens.

The Development of Analysis of Low Aluminium Contents in Steel. J. Jindra and F. Kühn. (*Vyzkumne Prace z Oboru Železa a Oceli*, 1958, 47–61). A colorimetric method with Eriochrome-cyanin and two spectrographic methods, one using Co as internal standard, the other without a standard are described.

Complexometric Titrations. XXXIX. Rapid Determination of Aluminium in Ferrosilicon. L. Brhaček. (*Chem. Listy*, 1958, **52**, (9), 1820–1822).

Photometric Determination of Tin in Iron and Steel. III. Photometric Method with Sodium Diethyldithiocarbamate and Its Application to the Determination of Tin in Iron and Steel. H. Goto and Y. Kakita. (*Nippon Kinzoku*, 1956, **20**, June, 319–322). Tin was coprecipitated from iron with MnO_2, and the complex salt was extracted with an organic solvent. This method enables 0·001% of Sn to be detected in 1 g of sample.—K. E. J.

The Problem of Increasing Reproducibility in Spectrographic Analysis. I. K. Maiboroda. (*Zavods. Lab.*, 1958, **24**, (6), 748–750).

The Problem of the Use of Carbon Electrodes for the Spectrographic Analysis of Steel. E. S. Kudelya. (*Zavods. Lab.*, 1958, **24**, (6), 752–753). Problems connected with the use of carbon and graphite electrodes in the analysis of steel are discussed, in particular the effect of carbon diffusion.

Flame Spectrographic Analytical Investigation of Ferrite Composition in Steels. (*Forsch. Wirts. Nordrhein-Westfalen*, No. 50, 1953, pp. 34). Electrolytic isolation of the carbides in Cr–Mn steels and the electrolytic solution of ferrite in citrate solution are described. The apparatus used for flame spectrographic analysis of the solution for Fe, Cr, and Mn in presence of excess alkali salts is shown and analyses are given.

Studies of Quantometer Analysis. III. Quantitative Analysis of Small Contents of B, Sn, and Al in Iron and Steel. Y. Oto, T. Hamaguchi, C. Matsumoto, T. Yoshinaka, and N. Nakao. (*Nippon Kinzoku*, 1956, **20**, June, 315–319). Spark methods of arc-like discharge were found to give satisfactory results; the spectral lines of B and Sn were interfered with by Fe, but this trouble was eliminated by using second-order lines. Arc-like conditions and photoelectric methods enabled rapid analyses of B, Al, Sn, and Cr to be made. (10 references).

The Duration of the A.C. Arc in Quantitative Spectrographic Analysis. V. P. Borzov. (*Zavods. Lab.*, 1958, **24**, (6), 756–757). The effect of arc duration at various current levels on intensity ratios is examined.

Spectrographic Analysis of Steel with the Modernized FES-1 Instrument. N. V. Buyanov, S. L. Zubkovskii, T. V. Kovalenko, V. F. Korotkov, and V. R. Lindstrem. (*Zavods. Lab.*, 1958, 24, (6), 703–708). Methods are given for the spectrographic analysis of carbon, low and high alloy steels, and ferro-alloys.

Determination of Phosphorus in Steel by Direct Spectrographic Analysis. A. Hans, M. Lacomble, L. Charlet, and I. Houbart. (*Groupement pour l'Avancement des Méthodes d'Analyse Spectrographique des Produits Métallurgiques*, 19th Congress, Sept., 1956, 155–175).

The special equipment and technique adopted by C.N.R.M. to overcome difficulties connected with the spectrographic determination of phosphorus, particularly interference by copper lines, are described.—L. D. H.

Carbon Determination in Chromium–Nickel Steels by the Spectrographic Method. E. S. Kudelya. (*Zavods. Lab.*, 1958, (4), 458). For these steels containing 8–20% Ni the author recommends the determination of carbon on a spectrograph with high dispersion by using a fixed magnesium electrode (commercial Mg) which suppresses the spectrum lines of nickel. The procedure is explained fully.—L. H.

Spectrochemical Analysis of Structural Constituents in Steels after Their Isolation. (*Forsch. Wirts. Nordrhein-Westfalen*, No. 48, 1953, pp. 31). Spectrographic procedures are described and their application to the examination of oxide inclusions and carbides explained.

Determination of Copper in Steel by Spectrographic Analysis. G. A. Klyushin. (*Zavods. Lab.*, 1958, (4), 457). The source of the spectrum is an a.c. arc with a magnetic field. Copper can be detected in amounts between 0·05 and 0·45%. The main conditions of the analysis are: current in arc 4 A, in the electromagnetic coil 0·5 A. Winding turns in coil 800. Fixed electrode disk containing 0·05% copper.—L. H.

Study of Hydrogen in Chromium Plated Steel Using a Mass Spectrometer. C. Levy and G. Consolazio. (*Chrome Dur*, 1958, March, 1–6). At all temperatures between 100° and 800° C the liberation of H_2 from Cr plated steels follows an asymptotic curve. Below 350°, H_2 proceeds from the Cr layer while above 490° it comes essentially from the steel.—A. G.

Spectrographic Determination of Trace Elements in Steel Without Previous Separation. F. Wever, W. Koch, and S. Eckhard. (*Forsch. Wirts. Nordrhein-Westfalen*, 1958, No. 519, pp. 36). Use of the ARL-grating spectrograph with a high tension arc of 4400 V detects 0·0001%Al and 0·0003%Mn. Apparatus is shown and results are given.

The Colorimetric Determination of Aluminium in Steel with Solochrome Cyanine R. P. H. Scholes and D. V. Smith. (*Analyst*, 1958, **83**, Nov., 615–623). The range 0·001–0·035% is covered. Higher concentrations can be determined by the use of aliquots.

The Determination of Trace Amounts of Aluminium in Cast Iron. R. C. Rooney. (*Analyst*, 1958, **83**, Oct., 546–554). Major constituents are removed with diethyldithiocarbamate in chloroform and the Al is extracted as cupferrate at pH 4·5 and polarographed with Solochrome violet R.S.

Ethylenediaminetetra–Acetic Acid and Allied Compounds in Metallurgical Analysis. E. G. Brown. (*Metallurgia*, 1958, **58**, Sept., 149–159). The author reviews the literature of the last few years dealing with the use of EDTA in metallurgical analysis. The ferrous section gives data on the determination of Al, Be, Co, Cu, Mg, Mn, Se and S, with a reference to the use of EDTA as a screening agent in the qualitative examination of special steels. (83 refs.).

Solochrome Black 6BN. K. E. Langford. (*Electropl. Met. Fin.*, 1958, **11**, Aug., 271). A letter. Solochrome Black 6BN is much more stable than Solochrome Black W.D.F.A., when used as an indicator in E.D.T.A. titrations. The endpoint is sharp, and for water analysis the dye may be mixed in solution with NH_4Cl–NH_4OH buffer, without deterioration after 2 months.

Metallurgical Absorptiometry and Spectrophotometry. II. E. C. Pigott. (*Murex Rev.*, 1958, **1**, (19), 571–586). Two-cell photoelectric instruments are reviewed with full details of equipment and operation. Absorptiometric chromatography is then reviewed.

Emission Spectroscopy. A.S.T.M. Committee E-2. (*A.S.T.M. preprint*, 1958, (59), pp. 11). Terms relating to spectroscopy are defined.

Spectrochemical Evaluation of Steels by Means of Transfer on to Counter-Electrodes. A. Garrido Bartolome. (*Min. y Met.*, 1958, **18**, Feb., 23–24). [In Spanish]. An arc is struck between the flat surface of the steel sample and an upper electrode. A variety of upper electrode materials were tried, but copper gave the best results. After the arc, the steel is replaced with another copper electrode, then sparking and recording follows. This technique gives a dilution, in effect, of the sample and the line pair, Fe_{II} 2714·4 Å and Cr_{II} 2860·9 Å, give a linear relationship up to 27% chromium. The linear relationship using the copper-steel sample electrodes only holds to 17% chromium.—P. S.

Symposium on Spectrochemical Analysis for Trace Elements. (*ASTM S.T.P.*, 221, 1958, pp. 79). **Emission Spectrometric Determination of Oxygen in Metals.** V. A. Fassel, W. A. Gordon and R. W. Tabeling. (3–22). Steel is included. About 11 samples can be spectrographed in 1 h and about 60 determinations can be made in a day. This might be halved by using electronic detectors for direct measurements. (38 refs.). **Spectrographic Determination of Trace Elements in Metals.** J. A. Norris. (23–38). Methods for Ag, Al, B, Ce, Co, Cu, Cr, Mn, Mo, Ni, P, Pb, Si, Sn, Ti and V in iron are noted. **Trace Analysis by Means of the Graphite Spark.** J. M. Morris and F. X. Pink. (39–46). Mainly semi-conductor analysis. **Spectrochemical Analysis for Trace Elements in Geological Materials.** K. J. Murata. (67–79).

The Use of Radioisotopes in Metallurgical Research and Industry. A. Kohn. (*Met. Rev.*, 1958, **3**, (10), 143–201). An exhaustive review of all aspects with 161 refs.

A System of Ore Mineral Identification. S. H. U. Bowie and K. Taylor. (*Min. Mag.*, 1958, **99**, Dec., 337–345). Reflectivity and hardness measurements are used.

Symposium on Radioisotopes. (*A.S.T.M. S.T.P.*, No. 215, 1958, pp. 94). This was held in Sept., 1956 at Los Angeles. **Electroplating and Metal Preservation Studies Utilizing Radioisotopes.** S. L. Eisler (5–13). The dilution method for sulphate analysis and study of the chromium sulphate complex, the use of two tracers simultaneously to study chromate suplementary coatings for Zn and Cd, the determination of Ni porosity and the use of a γ-source as a liquid level gauge. **Autoradiography as a Testing Technique.** M. J. Schlesinger and H. J. Gomberg. (20–29). **Activation Analysis for Industry.** A. DeHaan. (54–61). **Thickness, Density and Concentration Gaging with Radioisotopes.** R. L. Newacheck, J. Kohl and D. L. Forrest (62–72). **Will ASTM Standards be Influenced by Radiation Effects in Metals?** J. C. Wilson and R. G. Berggren. (73–80). Changes in steels on irradiation are tabulated and discussed.

A Photometric Method for the Determination of Tungsten in Low-Grade Mine Ore and Mineral Dressing Products. J. B. Pollock. (*Analyst*, 1958, **83**, Sept., 516–522). Rhodamine B is used as reagent.

The Automatic Determination of Sulphur Trioxide in Flue Gases. P. H. Crumley, H. Howe and D. S. Wilson. (*J. Inst. Fuel*, 1958, **31**, Sept., 378–382). A photoelectric method of measuring the density of a $BaSO_4$ precipitate is used. the SO_3 being absorbed in *iso*propyl alcohol.

The Standardization of Methods of Analysis of Coal and Coke. J. G. King. (*Fuel*, 1958, **37**, Oct., 407–408). Notes on B.S. 1016 parts 6 and 7 are given.

The Determination of Carbon and Hydrogen in Coal and Coke by the Liebig Method: Elimination of the Errors due to the Formation of Nitrogen Dioxide. M. P. Mendoza. (*Fuel*, 1958, **37**, Oct., 409–414). Absorption in granular MnO_2 is advocated and a correction for H_2 is suggested.

Evolution of Oxides of Nitrogen and of Sulphur during the Determination of Carbon and Hydrogen in Coal. A. H. Edwards. (*Fuel*, 1958, **37**, Oct., 415–419). Absorption in MnO_2 is shown to be effective.

INDUSTRIAL USES AND APPLICATIONS

Steel. A.S.T.M. Committee A-1. (*ASTM* 1958 *preprint*, (1), pp. 91). Recommendations for previous standards are made and tentatives are issued for uncoated stress-relieved wire for prestressed concrete, butt welds in still tubes for refinery service, seamless and electric welded low-alloy steel tubes for economizers, steel sheets for porcelain enamelling, hot-rolled carbon steel strip, commercial quality, centrifugally cast ferritic alloy steel pipe for high-temperature service, factory-made wrought carbon steel and alloy steel welding fittings of seamless or welded construction for low-temperature service, cold-rolled carbon steel strip, hot-rolled carbon steel strip of structural quality, low-carbon steel externally and internally threaded standard fasteners, quenched and tempered steel bolts and studs with suitable nuts and plain hardened washers, quenched and tempered alloy steel bolts and studs with suitable nuts, magnetic particle testing and inspection of heavy steel forgings, and wrought alloy steel rolls for cold and hot reduction.

Steels for Extrusion Tools. F. Rodgers. (*J. B'ham. Met. Soc.*, 1958, **38**, Dec., 117–138; *Met. Ind.*, 1958, **93**, Nov. 28, 449–452; Dec. 5, 469–473). The conditions under which liners, liner holders and containers work and grades of steel recommended for the extrusion of non-ferrous metals are given. Heat treatments for suitable grades of steels and selection for rams, mandrels and dies are indicated.

Steels for the Petroleum Industry. A Comparison of British and American Qualities. Part 2. F. A. Kirk and J. Williams. (*Corros. Techn.*, 1958, **5**, Nov., 357–360). This article is a condensed version of a paper presented at the 1957 International Petroleum Equipment Conference; this section compares British and American specifications for stabilized austenitic and some recent special steels.

Low-Carbon Manganese–Chromium–Molybdenum–Vanadium Steel for Pressure Vessels. I. M. Mackenzie. (*Alloy Met. Rev.*, 1958, **9**, Sept., 2–8). A description of Ducol "W30" steel with U.T.S. exceeding 34 tons/in² and better suited to welding than are higher-tensile C–Mn steels is given. It contains 0·15%C, 1·3%Mn, 0·5%Cr, 0·26%Mo and 0·08%V. Properties and applications are discussed.

HISTORICAL

An Early Medieval Iron-smelting Site in Weardale. R. F. Tylecote. (*JISI*, 1959, **192**, May, 26–34). [This issue].

MISCELLANEOUS

Old Steel Preferred. (*Steel*, 1958, **143**, Nov. 10, 124). This article refers to the construction of a radiation-proof room in which studies can be made away from the influence of natural radiation. The thick steel walls are made from pre-1914 armour plate in which much of the radioactivity has decayed.

Preparation of FeO, NiO and CoO Crystals by Halide Composition. R. E. Cech and E. I. Alessandrini. (*A.S.M. preprint* 82, 1958, pp. 8). A description is given of the formation of these crystals on cleaved MgO crystals. Thicknesses up to 500 microns have been produced and examined.—E. E. W.

Heat Endurance, Heat and Work in the Metal Industry. W. Schweisheimer. (*Iron Steel*, 1958, **31**, Sept., 465–466). Types of clothing giving protection against extremes of heat and humidity are described. The effects of heat on the human body and on working efficiency are discussed.—A. G.

Errata
Vol. 189

May, 83*c*, line 12.
For "Graaf" *read* "Graef."
84*c*, line 9.
For "N.I." *read* "N.P."
87*b*, line 30 from bottom.
For "Grise" *read* "H. H. Grix."
Aug., 369*c*, line 10.
For "M. G. Liégeois" *read* "G. Liègeois."
375*c*, line 38.
For "Eberie" *read* "Eberle."
377*a*, line 50.
For "B.A." *read* "A.B."

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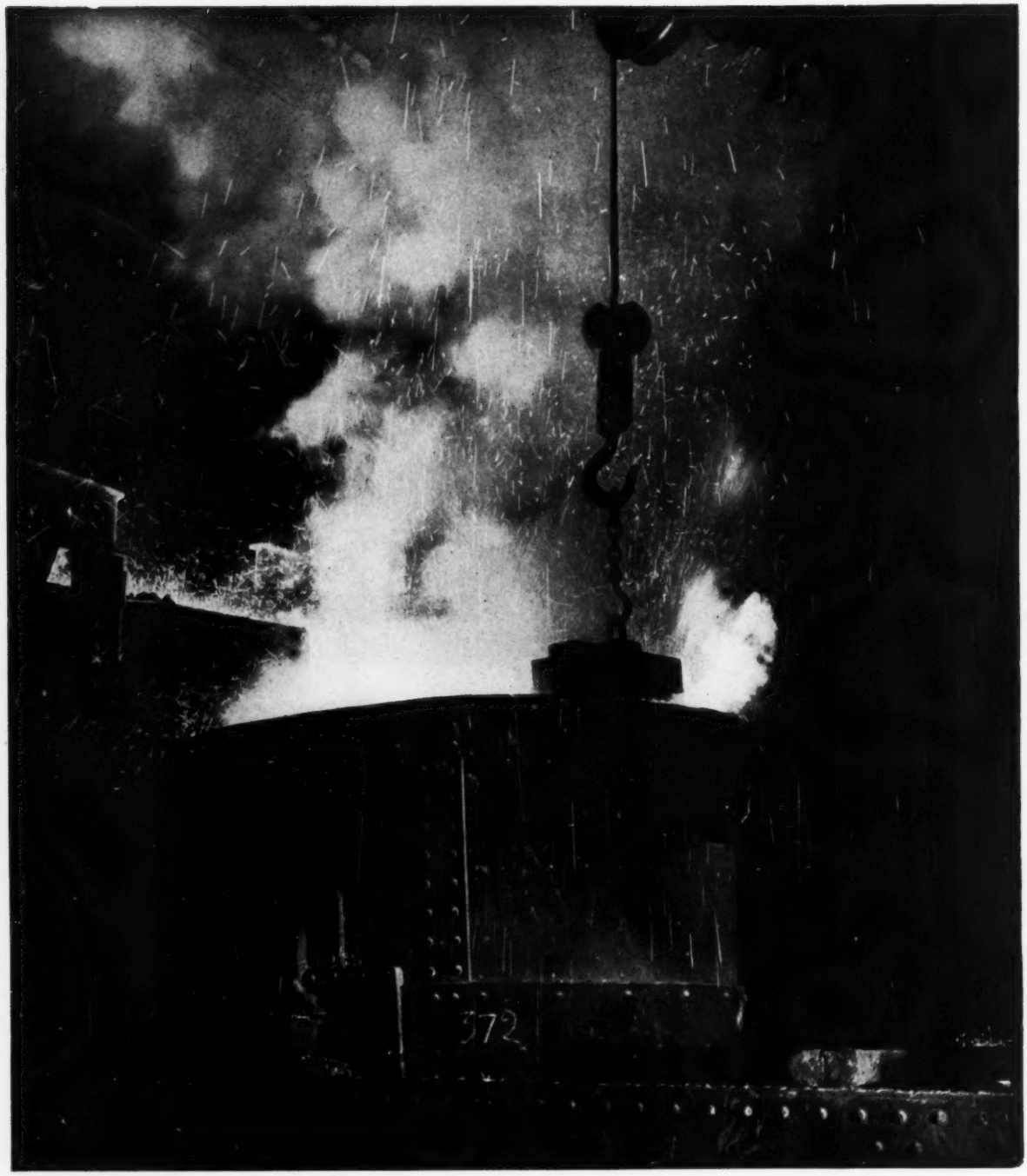

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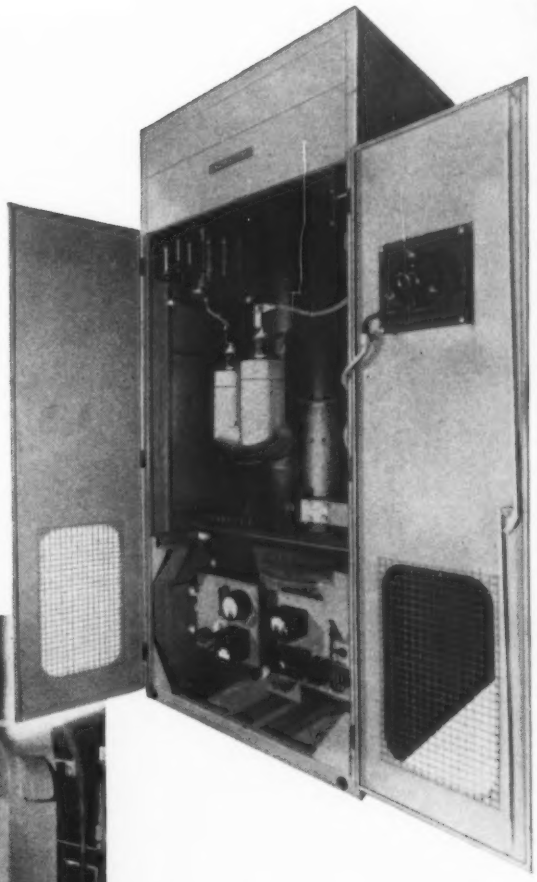

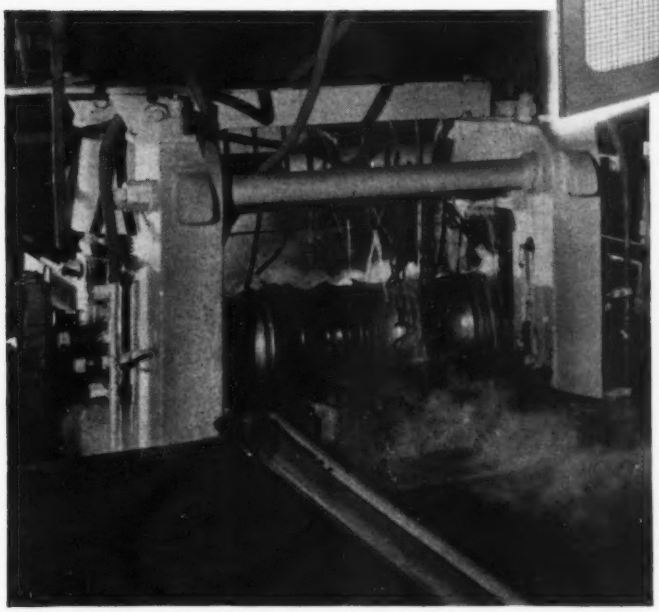

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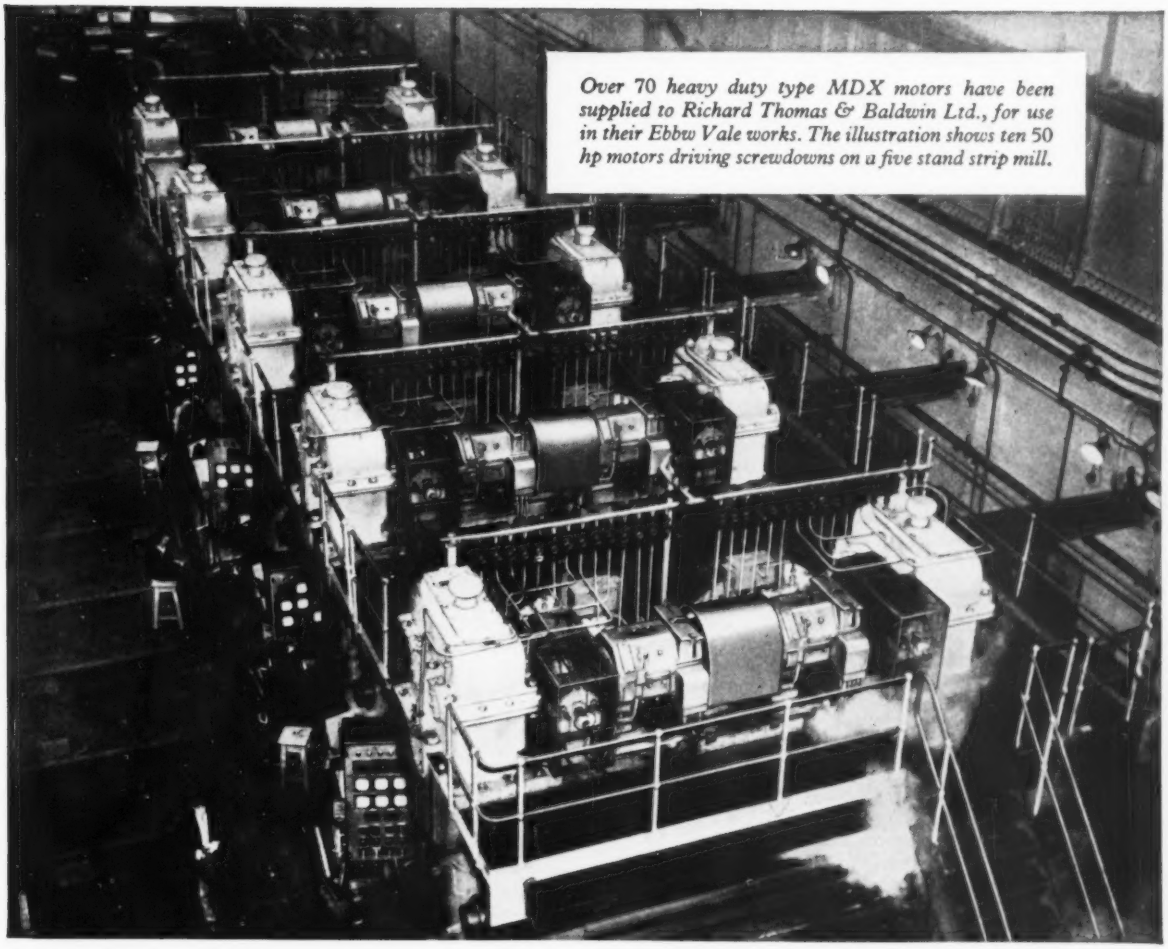

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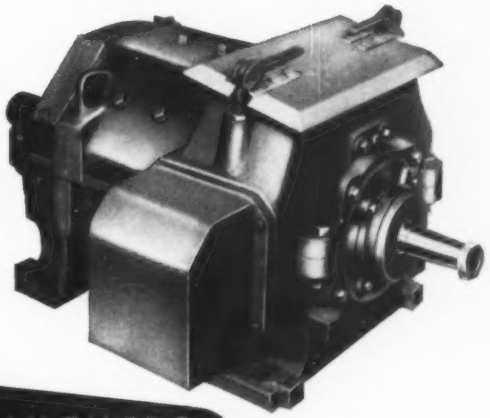

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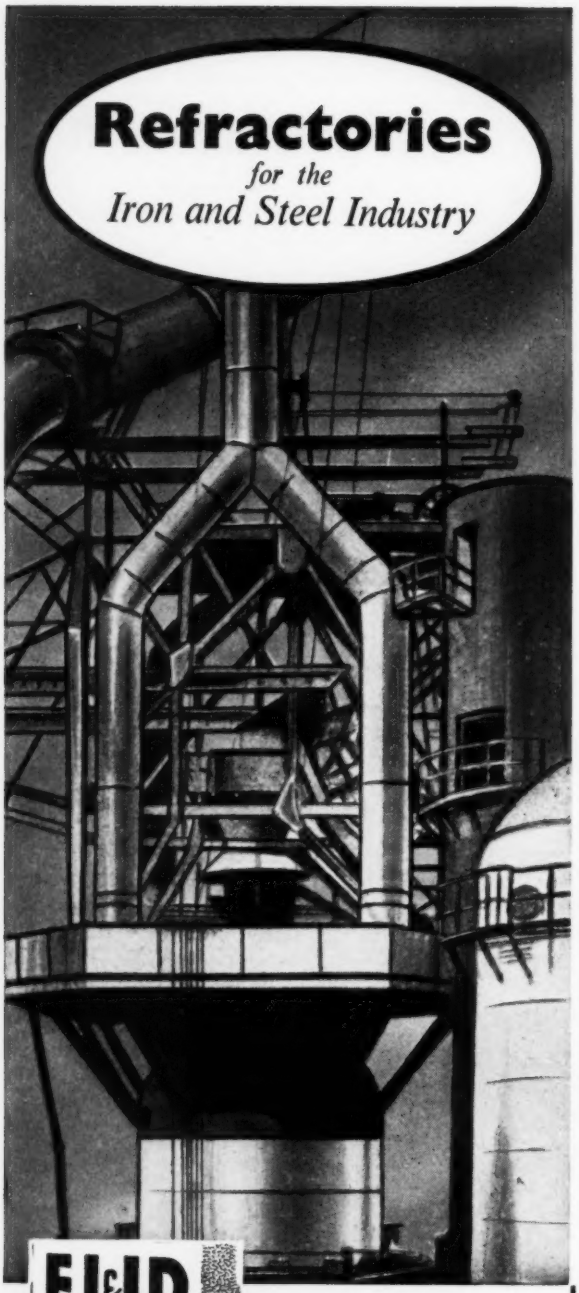

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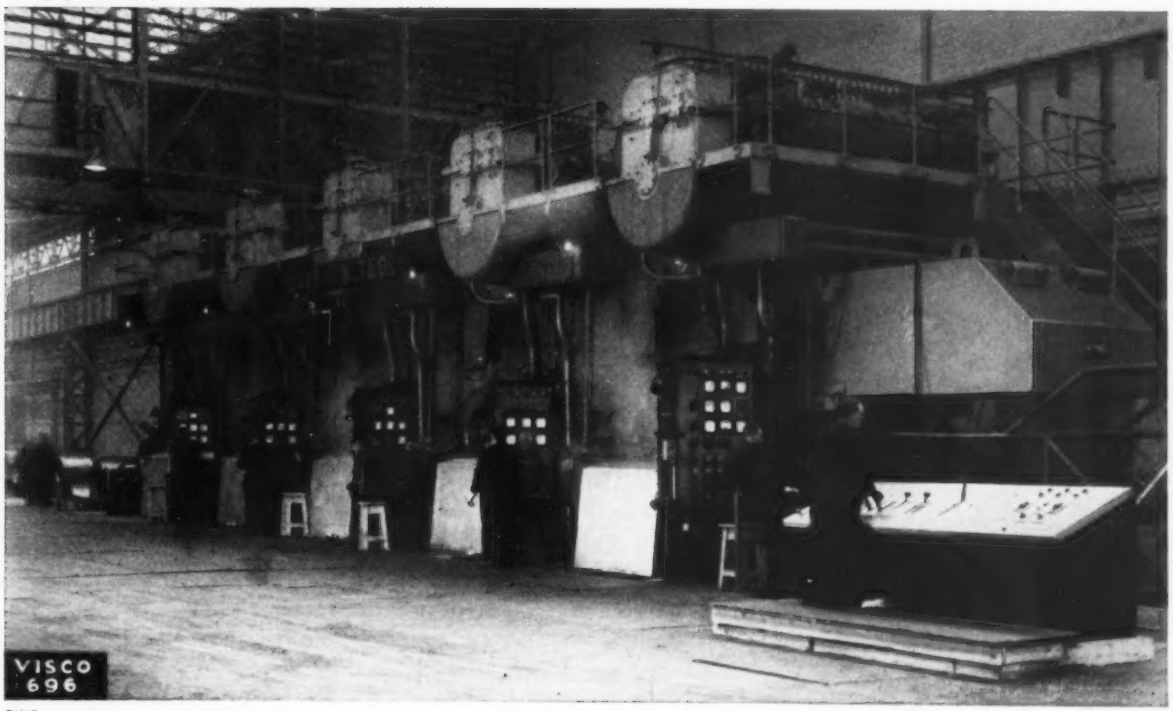

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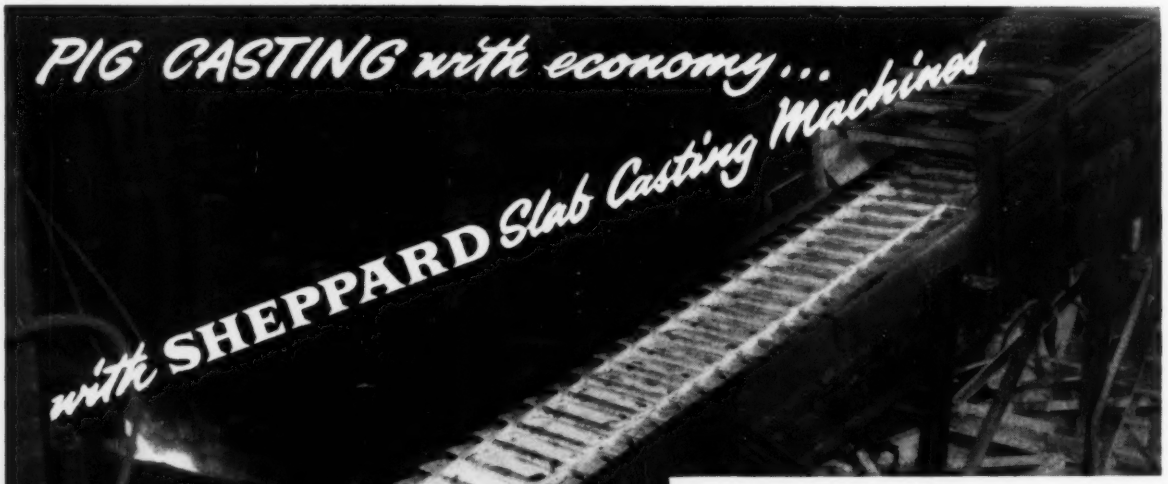

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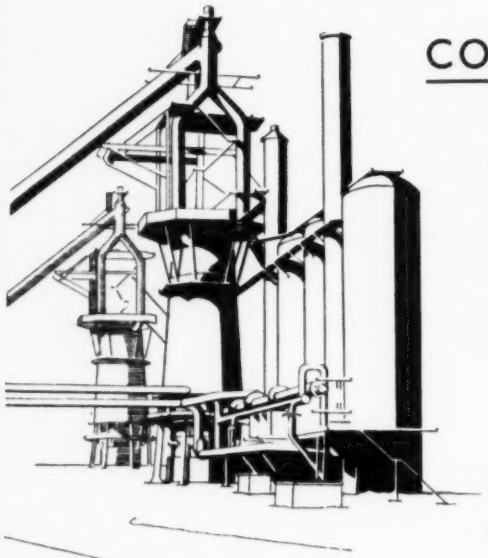

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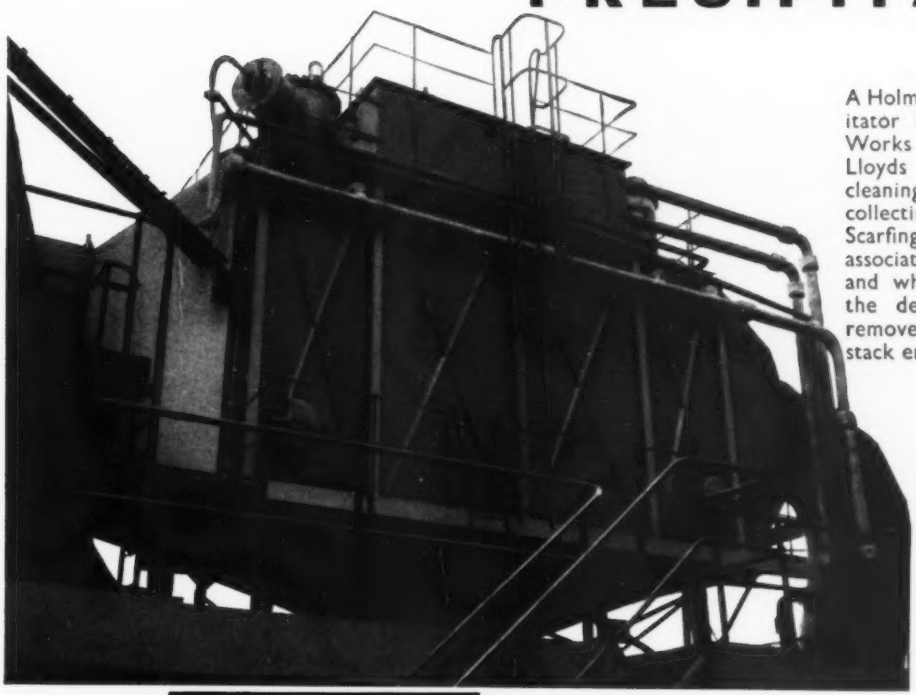

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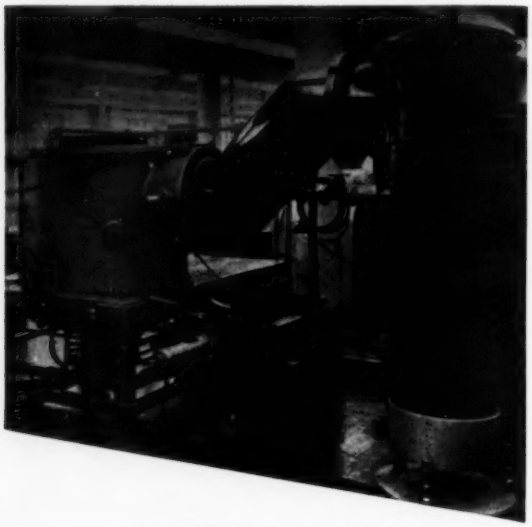

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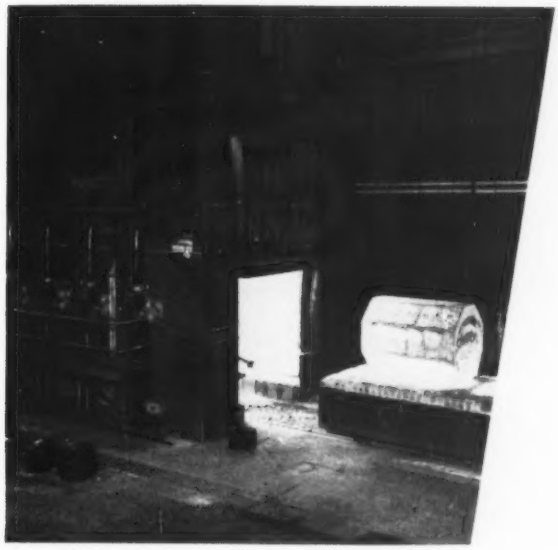

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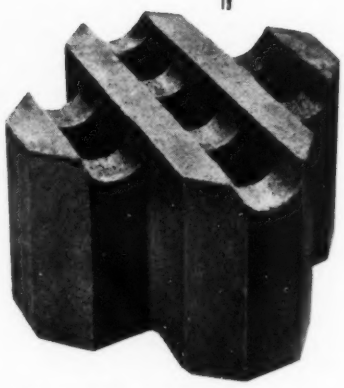

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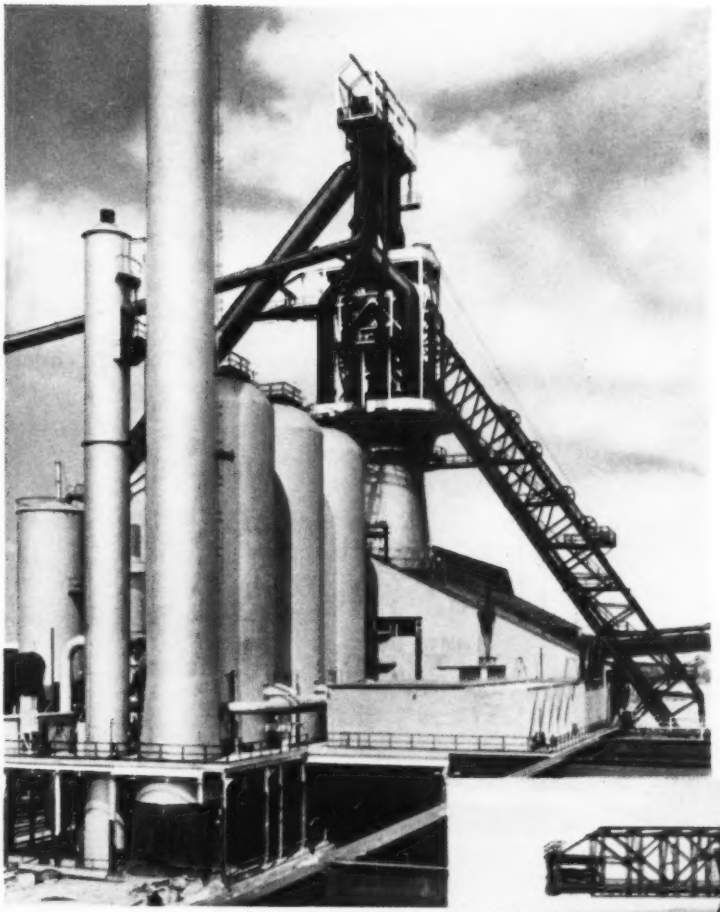

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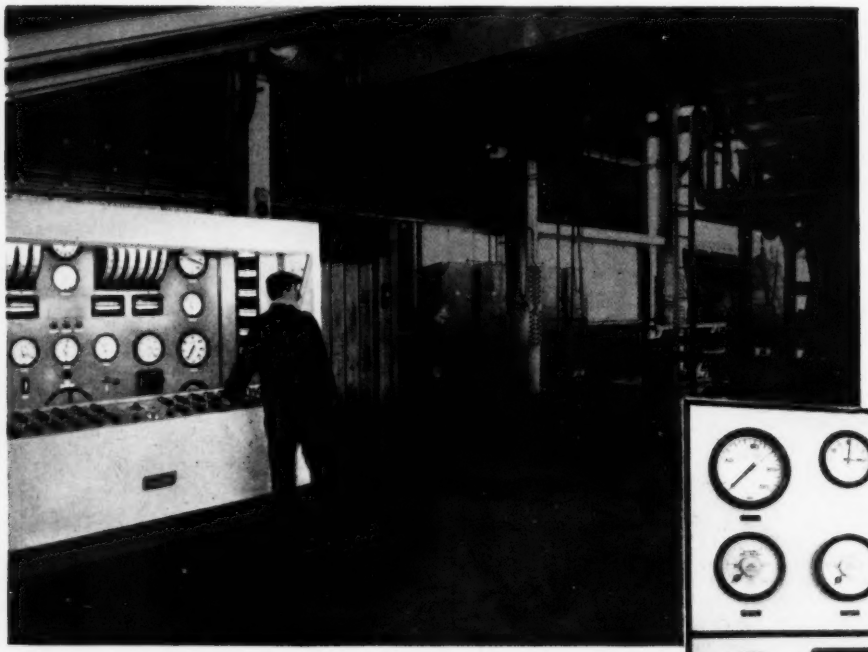

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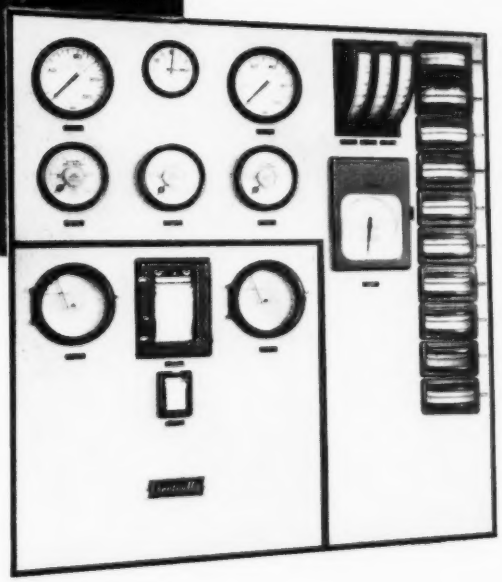

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